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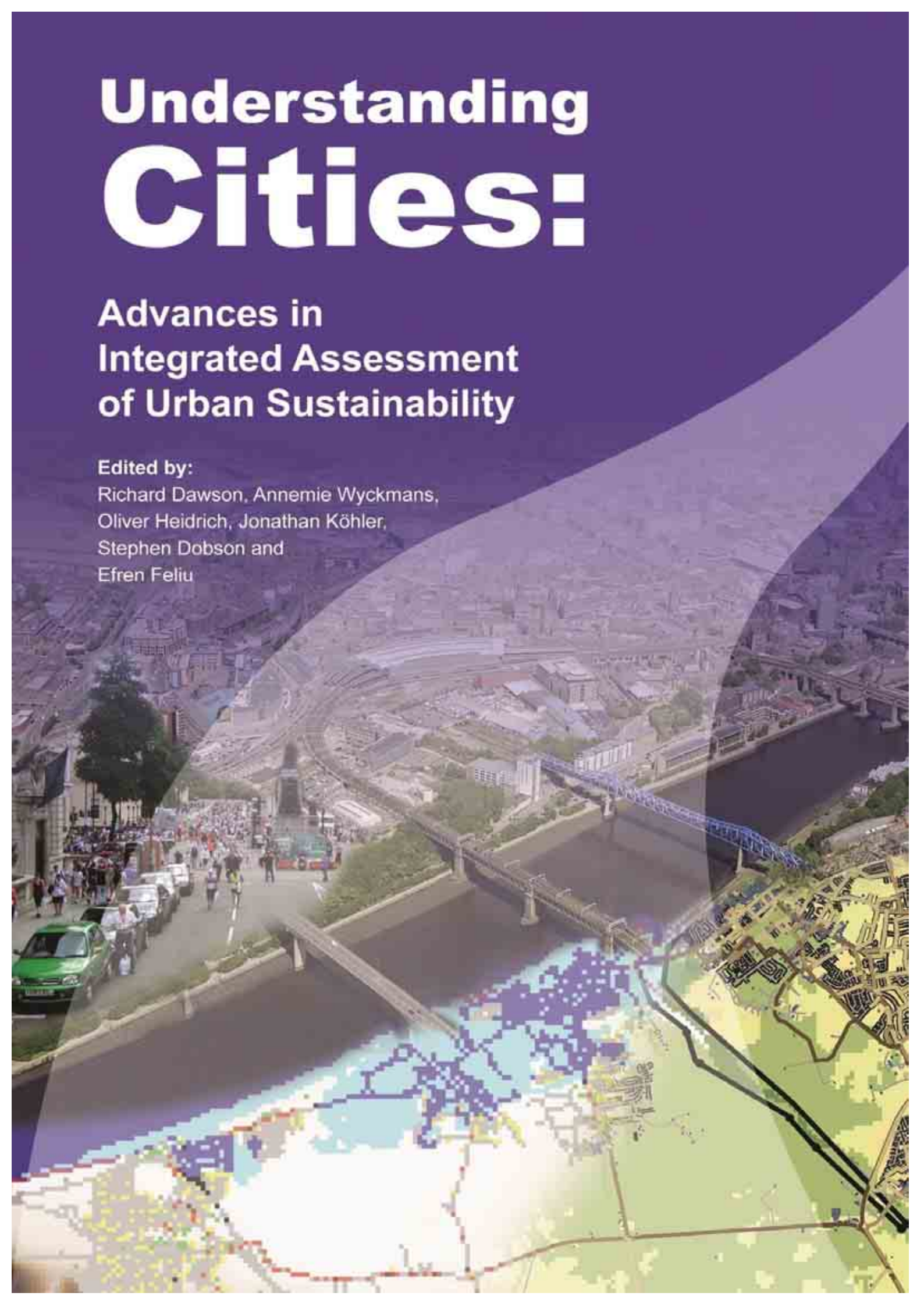
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Understanding Cities:

Advances in Integrated Assessment of Urban Sustainability

Edited by:

Richard Dawson, Annemie Wyckmans,
Oliver Heidrich, Jonathan Köhler,
Stephen Dobson and
Efren Feliu



Understanding Cities:

Advances in integrated assessment of urban sustainability

The urgent need to reconfigure urban areas to consume fewer resources, generate less pollution, be more resilient to the impacts of extreme events and become more sustainable in general, is widely recognised.

To address these issues, requires integrated thinking across a range of urban systems, topics, issues and perspectives that are traditionally considered separately.

This book introduces key results from the European Science Foundation funded COST Action TU0902 network that brought together researchers and practitioners involved in urban integrated assessment.

Using case studies, theoretical approaches and reporting experience from across Europe this book explores the challenges and opportunities of urban integrated assessment through four perspectives:

- (i) Quantified integrated assessment modelling;
- (ii) Climate change adaptation and mitigation;
- (iii) Green and blue infrastructure; and,
- (iv) Urban policy and governance.

The book closes by outlining priorities for future research and development and presents a generic framework for urban integrated assessment to analyse the potential benefits and trade-offs of sustainability policies and interventions.

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Understanding Cities:
Advances in integrated assessment of urban sustainability

Editors:

Richard Dawson, Newcastle University, U.K.

Annemie Wyckmans, NTNU, Norway

Oliver Heidrich, Newcastle University, U.K.

Jonathan Köhler, ISI Fraunhofer, Germany

Stephen Dobson, Sheffield Hallam University, U.K.

Efren Feliu, Tecnalia, Spain



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Preface

This all started after a series of symposia and meetings, where a number of research groups working on similar, innovative, yet very challenging problems related to city scale integrated assessment kept bumping into each other. Many of these initiatives were large, well-resourced, national research programmes – such as the *Tyndall Centre for Climate Change Research Cities Programme* in the UK, or the *Potsdam Institute for Climate Impacts: Sustainable Hyderabad* in Germany. A group of us quickly recognised that formation of a network would be an ideal mechanism to build up this activity across Europe, engage each other in a targeted forum, share ideas, experiences and methods to help advance our collective understanding.

The European Science Foundation funded COST (European Cooperation in Science and Technology) Action network proved to be an ideal mechanism. As a ‘bottom up’ network, COST Actions provide a natural mechanism for engaging with other researchers undertaking urban integrated assessment who were previously unknown to the original network organisers. This did pose challenges – some of the original objectives and priorities evolved to reflect the constituent members of the Action, but also we were able to adapt and incorporate new knowledge and thinking.

Perhaps the greatest challenge was orchestrating the extremely diverse background of Action members from 26 participating countries in Europe, and further partners from outside Europe. This was inevitable given the topic of the Action, but I consider the level of cooperation achieved - despite this breadth of backgrounds - to be clear evidence of our success at integrating our own activities and breaking down disciplinary barriers and deliver highly visible outputs.

Many of the findings and concerted research efforts of the network are captured in this book – but just as many are still being finalised or were not appropriate for reporting here. A permanent web archive has been set up at:

<http://www.ncl.ac.uk/ceser/researchprogramme/costactiontu0902/>

and I expect that it will be added to for some time as Action members further exploit the data collated over the last few years. When reading this work, it is important to remember that COST Actions do not fund research time, rather they provide funds for meetings, workshops and secondments to grow communities from the ‘bottom up’, break down inter-disciplinary and international barriers. Thus, much of the reported work in this volume add value to other studies through comparison, benchmarking or joint case studies.

In February 2013, Efren Feliu at Tecnia held a very successful Training School for early stage researchers and city officials with responsibility for sustainability and/or climate change issues. The school attracted officials from a wide range of cities that include Stockholm, London, Plovdiv and Cascais. The positive feedback we received made the event so worthwhile, and a number of the COST Action ‘teachers’ have since been invited to contribute to other training events and visit individual cities. This is just one example of how this COST Action made a significant impact. A number of early stage researchers (and some more senior researchers!) have benefitted from secondments to other institutions to advance their research in new inter-disciplinary directions and ensure the capacity of European scientists into the future. Findings from several of our peer-reviewed journal papers have even been reported in national and international news outlets, including the BBC (U.K.), Le Figaro (France) and Panorama (Italy).

Although I led the coordination of the original proposal, I would never have undertaken this endeavour, or been successful without the support and input of Dr. Diana Reckien (formerly PIK, Germany, now Columbia University, New York), Prof. Darryn McEvoy (formerly at Maastricht University, now at RMIT, Melbourne), Dr. Jonathan Kohler (ISI Fraunhofer, Germany) and Professor Jim Hall (Oxford University, U.K.).

Despite the many rewarding experiences and excellent outputs running a network, particularly where no funds to directly support staff time, is extremely hard work. My thanks go to all the COST Action members and management committee who contributed to this edited book, delivered many other outputs not included here (which can be found on the webpage above) and provided stimulating input and discussion at our meetings. Furthermore, we have benefitted from input from some excellent and dynamic guest speakers from around the world – including Jon Fink (Portland State University), Peter Newman (University of Perth), Michael Neuman (University of New South Wales), Astrid Westerlind Wigström (ICLEI), Juergen Kropp (Potsdam Institute for Climate Impact Research) and many more leading academics and policy makers.

Crucial to the success of the COST Action was the support of the working group leaders: Jonathan Köhler (ISI Fraunhofer), Mika Ristimäki (SYKE, Finland), Oliver Heidrich (Newcastle University), Diana Reckien (Potsdam Institute for Climate Impacts, then Columbia University), Johannes Flacke (University of Twente), Christopher Koroneos (Aristotle University of Thessaloniki), Rolf Bohne (NTNU, Norway), Petra Amparo López Jiménez (Universitat Politècnica de València), Annemie Wyckmans (NTNU, Norway) and Steve Dobson (Sheffield Hallam University) – their constant enthusiasm, motivation, effort and coordination skills were the engines of delivery for the Action.

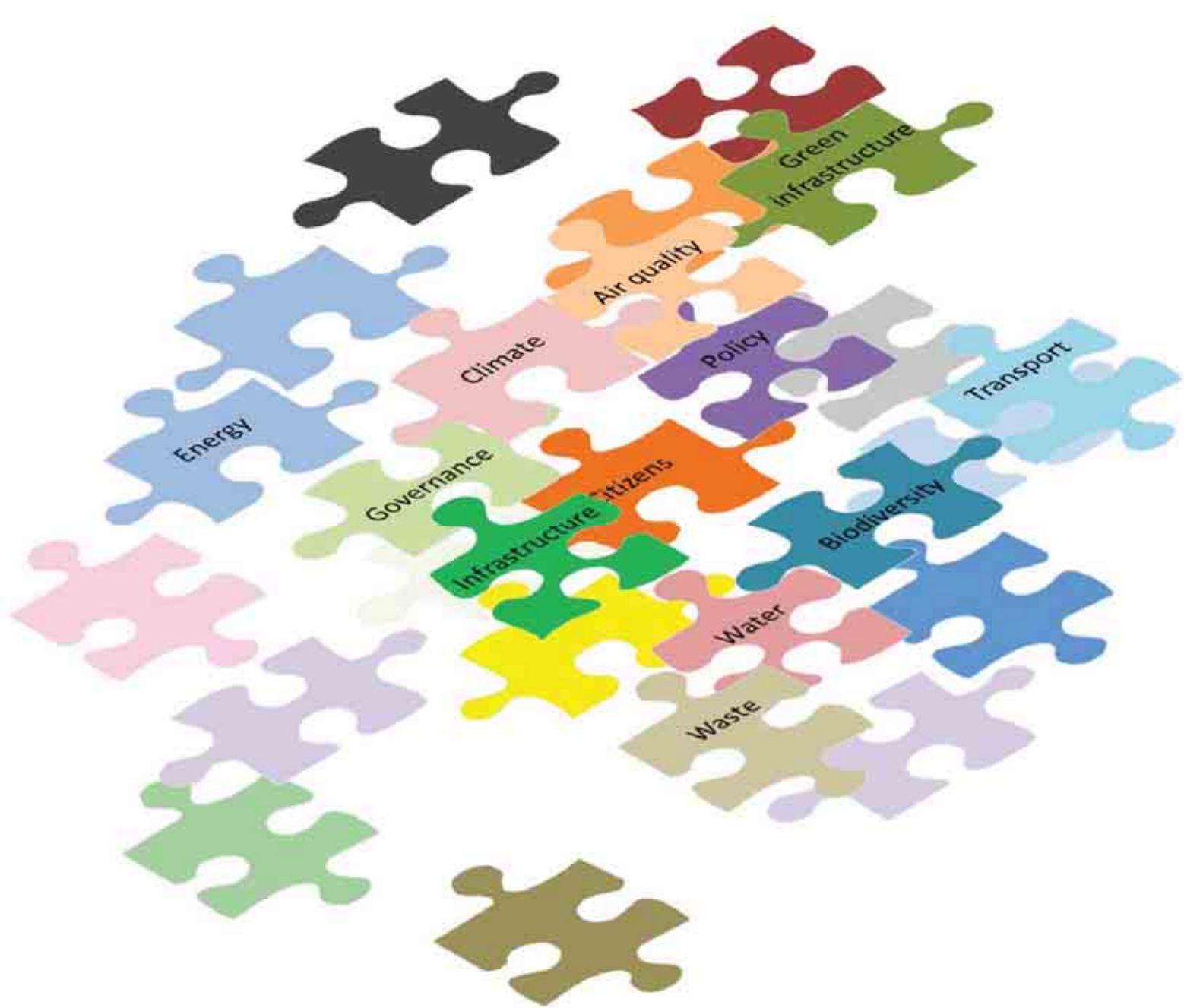
Particular thanks are owed to first Diana Reckien and subsequently Annemie Wyckmans (who stepped up when Diana was awarded a fellowship at Columbia University in the USA) who also took on the role of vice-Chair. Similarly, Steve Dobson deserves special thanks for taking on the organisation of the final conference. One of the most important, and certainly the most time consuming role, was taken on by Efren Feliu from Tecnalia in Spain. Without his management of the COST grant, the Action could not have run as smoothly and successful as it did.

My final thanks are saved for Thierry Goger (COST Office Transport and Urban Domain science officer for all but the final months of the Action), Terje Kleven (the Transport and Urban Domain rapporteur) and Carmencita Malimban for seeing us through the bureaucracy and helping us to focus on the work!

Finally, on a personal note, which hopefully reflects the sentiments from all 80 or so Action members, the opportunity to visit researchers from across Europe and explore their countries has been stimulating from intellectual, cultural and social perspectives. The connections and friendships made over the last four years will, I am sure, outlast the funding of the network!

Richard J. Dawson
Newcastle University, UK
Chair of COST Action TU0902

February 2014



Understanding Cities: The imperative for integration

Section I

Understanding Cities: The imperative for integration

Richard J. Dawson¹, Johannes Flacke², Monica Salvia³, Filomena Pietrapertosa³

¹ School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne; NE1 7RU, U.K.;
richard.dawson@newcastle.ac.uk

² University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), PO Box 217, 7500 AE
Enschede, The Netherlands; j.flacke@utwent.nl

³ National Research Council of Italy - Institute of Methodologies for Environmental Analysis (CNR-IMAA), C. da S.
Loja; 85050 Tito Scalo (PZ), Italy; monica.salvia@imaa.cnr.it; filomena.pietrapertosa@imaa.cnr.it

Highlights

- An introduction to the challenges facing urban areas and the urgent need to make them more sustainable.
- A key challenge is the complexity of cities that leads to non-linear and unintended consequences of, often well meant, interventions.
- Underlines the case for a more integrated response to deliver more sustainable urban areas, and the need for a new generation of integrated assessment methods and tools to operationalise this.
- Introduces the structure of the rest of the book.

1 Introduction

The urgent need to reconfigure urban areas so that they consume fewer resources, generate less pollution (including greenhouse gases), are more resilient to the impacts of extreme events and are more sustainable in general, is widely recognised. With half the global population living in cities, and concerns about issues such as rates of resource consumption and adaptation to climate change being raised with increasing frequency, addressing the challenge of urban sustainability is now extremely urgent.

As centres of population and economic activity, urban areas represent concentrated opportunities for addressing issues of sustainability. However, this involves complex interactions of citizens, governmental/non-governmental organizations and businesses which can inhibit the development of integrated strategies (which may involve transportation demand management, land-use planning and construction of new civil infrastructure) whose combined effect can be more beneficial than the achievements of any single agency or organization acting unilaterally. This requires integration across sectors traditionally analysed independently e.g. water resources, transport, waste management and health, as well as the simultaneous effort to adapt cities to become more sustainable.

This volume introduces key results from the European Science Foundation funded COST Action TU0902 network, that ran from May 2009 to March 2014 to bring together researchers working on the intricate challenge of integrated assessment in cities to explore and share different case studies,

issues and methodological approaches. This Section explores the context to this problem by considering the drivers and pressures cities facing in the twenty-first century, what we have come to mean by terms such as urban sustainability and integrated assessment before discussing how integrated thinking is key to addressing the challenge of delivering sustainable urban environments.

2 Urban sustainability: the need for an integrated response

During the early phases of the COST Action we undertook a review of drivers and pressures, mechanisms for assessing sustainability and activities underway in 39 cities from the 26 countries represented in the network (Figure 1.1).

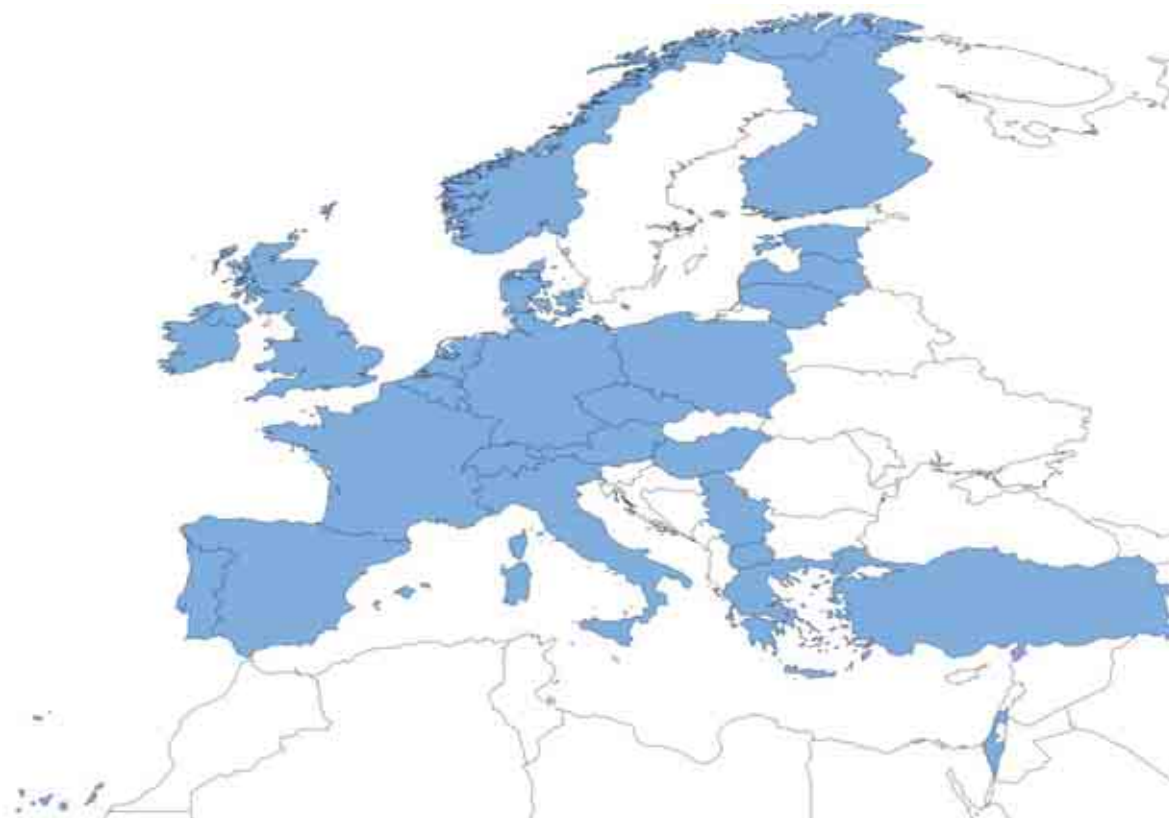


Figure 1.1 COST Action TU0902 member countries. The Action also had affiliate members from RMIT, Australia and Columbia University, U.S.A.

This review, summarised in part below, revealed both shared challenges and distinct differences across these cities. Pressures such as responding to climate change were common across all cities – although as is discussed in Section III of this volume the response is highly varied – but whilst some cities are expanding, others are contracting or have populations that are ageing. Similarly, as explored in Section V of this Volume, planning structures varied between countries, with urban areas having different amounts of devolved power and sustainability embedded into legislation to different degrees. These issues pose substantial challenges for urban planners and engineers seeking to deliver integrated responses.

2.1 Drivers and pressures in cities

Cities on the one hand concentrate cultural, technological and economic activity resulting in innovation and wealth, but can also concentrate problems and vulnerabilities. Moreover, they are subject to a wide range of long term drivers and pressures. Urbanisation is driven by social

processes that result in an increase in the population and/or extension of urban areas, and their associated changes to land cover – most visible through construction of buildings and other infrastructure. These drivers may include changes to: population, governance, employment opportunities associated with industrialisation, consumption patterns, international migration and accessibility (Seto and Kaufman, 2003; Sánchez-Rodríguez *et al.*, 2005). The twentieth century saw a, previously unanticipated, rate of urbanization. In 1900, the proportion of the global population people living in urban areas was only 14% (Douglas, 1994), this now stands at over 50% of the world's population (UN, 2010) – despite taking up only 0.24-2.74% of the Earth's land surface (Schneider *et al.*, 2009) – and is forecast to include more than two-thirds of the population by 2050 (UN, 2010). The rate of urbanisation has varied substantially between regions, and also led to the proliferation of slums which house 31.6% of all city dwellers (UN Habitat, 2003).

The density of people and infrastructure makes cities hotspots of vulnerability to natural hazards and long term climatic and environmental changes (Dawson, 2007). However, the severity of these impacts is mediated by social, economic and political factors such as the demographic structure of population, the strength of institutions and public infrastructure (Adger and Vincent, 2005). Whilst the most noticeable characteristics of urbanisation may be their buildings and infrastructure, urbanisation directly and indirectly has much farther reaching impacts. Globally, cities are major sources of greenhouse gases (GHG) directly (*e.g.* from petrol-based transport), and indirectly (*e.g.* through energy use and consumption of industrial and agricultural products) (Bicknell *et al.*, 2009; IEA, 2008). Similarly, consumption of resources and production of waste leads to land use changes and resource movements between other rural and urban areas (WRI, 2007; UNEP, 2012). These activities within and outside urban areas, mobilise heavy metals and other pollutants and disrupt nutrient cycles and ecosystems (Vitousek, 1994; Mannion, 1998; Falkowski *et al.*, 2000; Kaye *et al.*, 2006; McKinney, 2006).

As the global population rises and demand for goods, food, water, energy and other services increases, the challenge – and imperative – to create more sustainable urban areas is increasing. The possibility of leveraging the concentrations of activity in cities to address these challenges is appealing. Indeed, many cities are serious global economic players: 34 of the top 100 economies are cities (Hawthornthwaite *et al.*, 2009) and they are often better placed to respond to global issues at a local level as they can provide more direct communication between citizens and policy makers (Bulkeley and Betsill, 2003). Yet responding to the many, and often interacting, challenges of global change is placing new and complex demands on urban decision makers. For example, policy makers are setting national and international targets for mitigation of carbon dioxide and other greenhouse gas emissions (Committee on Climate Change, 2013) that imply reengineering of urban energy systems, transport and the built environment whilst demanding cities that are less vulnerable to natural disasters (Adaptation Sub-Committee, 2012). Clearly, this necessitates an integrated response that encompasses a whole range of urban functions, responsibility for which is usually fragmented across a number of citizens and organisations.

2.2 In pursuit of urban sustainability

There is a vast literature debating the definition of sustainability (van Pelt *et al.*, 1995; Ravetz, 1999; Haughton and Hunter, 2003; Newman and Jennings, 2008). To avoid this debate taking over network meetings, Action members quickly agreed that a definition of sustainability should

embrace economic, social and environmental factors, whilst taking a long term view to these issues that avoids compromising future generations.

Inevitably, local economic and social conditions means that the implications of this are specific to each city, but it is possible to identify some general goals that should increase the sustainability of any city pursuing them (Beatley, 2000; Kenworthy, 2006; Suzuki *et al.*, 2010; Bulkeley, 2010; Dawson, 2011):

- Creates the smallest possible ecological footprint,
- Environmentally friendly in terms of pollution, land use and climate change,
- Provides economic and social security,
- Citizens are healthy and lead high quality of life,
- Centres of culture and creativity,
- Inclusive governance system, and,
- Takes a long term view on allocation of resources and definition of benefits and cost, and,
- Is generally resilient to pressures and disturbances.

A starting point is typically to develop a long term vision (e.g. Moodley and Kerr, 2009; Eames *et al.*, 2009) that can unite policy makers, businesses, communities and other stakeholders around a common purpose and provide a framework for developing and implementing change.

2.3 Tradeoffs and synergies between sustainable interventions

Sustainable development strategies in cities should, as discussed previously, consider the a host of drivers that impact upon their physical processes, human-built infrastructure, economic, social and environmental systems. The breadth and diversity of sustainability measures and examples of best practise are well documented in other reviews (Rojas Blanco, 2006; Stockholm Stad, 2007; CABI, 2011; UKCIP, 2014; Clinton Foundation, 2014), but Dawson (2011) identifies some general classes of intervention:

- Building new engineering infrastructure (e.g. low carbon energy systems),
- Adapting existing buildings and infrastructure (e.g. retrofitting insulation),
- Reducing demand (e.g. demand management programmes, efficiency gains through technology),
- Increasing the resilience of natural systems (e.g. restoration of ecological services),
- Reducing impacts in the built environment (e.g. land-use planning, building codes),
- Reducing vulnerability (e.g. education programmes),
- Increasing adaptive capacity (e.g. more responsive governance structure)
- Adoption of market instruments (e.g. taxes and incentives to reduce emissions, insurance to spread risk),
- Monitoring to gain knowledge (e.g. remote sensing), and,
- Emergency management (e.g. warning systems, evacuation planning).

It is likely that most of these types of measure will be used in some way – indeed this is reflected in the vast majority of sustainability plans that were reviewed over the course of this COST Action. However, implementation of individual or multiple sustainability measures does not necessarily deliver systemic improvements – moreover, well-meant interventions can have negative impacts in other sectors or locations (Table 1.1). Strategies may constrain options in other sectors, for example strategies to constrain development on green spaces may limit possible transport routes and

opportunities for economic development. Typical impacts of *maladaptations*, measures that adversely impact upon other systems, sectors or social groups, are disproportionately burdening the most vulnerable, high opportunity costs, reduce incentive to adapt, and finally path dependency (Barnett & O'Neill 2009). Likewise, many interventions can be designed against individual 'events' which fail to take into account sustainability issues over a full range of drivers and pressures. For example, flood management strategies are not necessarily designed in concert with heatwave management strategies, yet the role of green space in both may be crucial.

Table 1.1 Examples of potential tradeoffs between sustainability objectives (after Dawson, 2011).

Response	Potential benefit	Potential negative impact
Air conditioning (Shimoda, 2003)	Reduce heat stress	Increase energy needs and consequently emissions
Densification of cities (Hunt and Watkiss, 2011)	Reduce public transport emissions	Increase urban heat island intensity and exposure to greater noise pollution
Desalination plants (Lundie et al., 2004)	Secure water supply	Increase greenhouse gas emissions
Irrigation (Eriksen et al., 2007)	Supplying water for food	Salinisation of soil, degradation of wetlands,
Biofuels for transport and energy (Cassman, 2007)	Reduce GHG emissions	Encourage deforestation; replace food crops raising food prices; can increase local air quality pollutants such as NO _x
Catalytic convertors (Amatayakul and Ramnäs)	Improve air quality	Large scale mining and international resource movements
Cavity wall insulation (CIRIA, 2003)	Reduce GHG emissions	Increase damages from a flood event
Raise flood defences (Kates, 1971)	Reduce flood frequency	Encourage more development (positive feedbacks)
Pesticides (Sheraga and Grambsch, 1998)	Control vector borne disease	Impact on human health, increased insect resistance
Conservation areas (Bunce et al., 2010)	Preserve biodiversity and ecosystems	Loss of community livelihoods
Insurance or disaster relief schemes (Fankhauser et al., 1999)	Spread the risk from high-impact events	Reduce longer term incentive to adapt
Traffic bypasses or radial routes (Wood et al., 2007)	Displaces traffic emissions from city centre, improving air quality and reducing noise	Can increase congestion and journey times (consequently overall greenhouse gas emissions)
Vehicle user charging (Gusdorf and Hallegatte, 2007)	Discourage vehicle use to reduce greenhouse gas emissions	Lead to greater social inequality

Despite an increased understanding of the synergies and conflicts in the objectives of sustainability strategies (Becken, 2005; Tol, 2005; McEvoy et al., 2006; Swart et al., 2007; Thornton and Combetti, 2013) and recognition that win-win (i.e. benefits across multiple sectors) or no-regret approaches should be sought (Sheraga and Grambsch, 1998) whilst managing negative impacts

(OECD, 2009), strategies and policies are often developed and implemented in isolation. There are a number of possible reasons for this (Biesbrock et al. 2007, Klein et al. 2005):

- Administrative scales: different policies and interventions are relevant to a range of spatial scales.
- Time frame: some interventions are relevant to short term investment seeking immediate solutions while others may require upfront investment for long term solutions (e.g. mitigation through reduction of greenhouse gas emissions).
- Stakeholder involvement: different types of stakeholders may be involved in different interventions.
- Indicators of success: Some interventions are readily measurable and amenable to targets, whilst others are difficult to quantify.
- Governance: Interventions will have different degrees of institutional complexity relevant to implementation.

2.4 Integrated assessment

Systems with interacting drivers such as urban areas have emergent properties (unexpected outcomes and consequences) which are a challenge for policy makers – particularly those used to dealing with linear systems over short timeframes. Clearly, it is meaningful to think about the many facets of urban sustainability in the same assessment framework and similarly, cities cannot be considered outside of a regional or global context. An integrated approach is therefore essential.

This is increasingly recognised, yet single sector analysis remains prevalent (Hunt and Watkiss, 2011). More developed studies consider a very limited range of interactions, or provide an ‘integrated’ summary statement. However, most recently a new generation of quantified integrated assessment methods are emerging. A range of approaches and how they have been applied to cities are explored in Section II of this volume.

Taking an integrated assessment approach enables us to take a long term view and re-frame the questions that are asked so as to link global, regional and local scales and their interactions in the context of future urban planning. This provides a more complete picture about how issues may evolve than is possible when taking a more conventionally sectoral view of problems. Additionally, integrated approaches provide an opportunity to explore not just model results or analyses, but how these relate with people and their urban area.

This is not just limited to urban areas - as Kelly et al (2013) note “*effective environmental management requires an understanding of the interactions between policy choices and complex social, economic, technical and environmental processes and elated aims*”. Many integrated assessments are associated with global scale analyses (e.g. Warren et al. 2008), but others are emerging to address a range of complex problems (e.g. Dawson et al. (2009) for coastal management).

3 Book structure and network disciplinary breadth

As the global population consolidates in urban areas, this book and the network from which it emerged were extremely timely. As policy makers aspire towards increasing sustainable development in cities, this book recognises that integrated thinking is essential to achieve this. However, this is not without risks and to fully maximise the benefits from integrated approaches advances in methodological approaches are required alongside shifts in governance and other systems.

This book is a final report of the COST Action. As a network, rather than funding new research, the emphasis of COST Action activities has been around synthesis and comparison of existing studies. This book does not report everything that the many Action members achieved, but it provides a summary of the four major themes of the network. Similarly, the breadth of the topic of urban integrated assessment means that no network or programme of work would be able to cover every aspect – although, as shown in Figure 1.2 the network brought together researchers and practitioners from a diverse set of backgrounds.

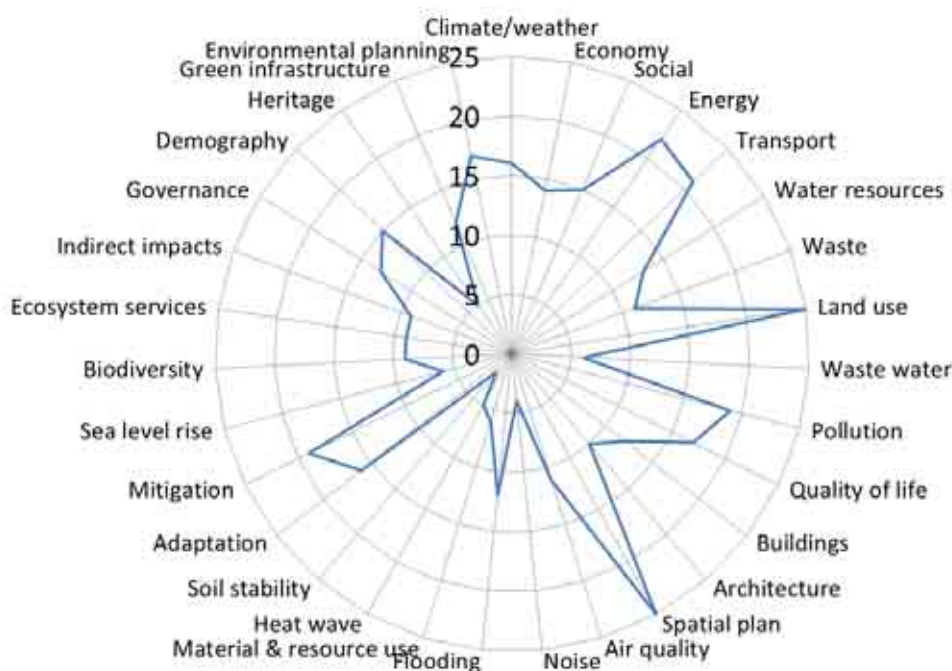


Figure 1.2 Number of network members with particular expertise.

This book focuses on four issues that became the major focal points of activity for the network. Each theme is reported in its own structure – some are compilations of distinct studies drawn together by an overarching introduction, whilst others are presented as a single element. Following this introduction, Section II reviews and discusses the challenges associated with integrated assessment modelling of urban areas through review of a number of city-scale studies. Section III and 4 consider two specific sustainability responses: climate change adaptation and mitigation, and green infrastructure respectively. Following discussions with city officials, these topics soon emerged as sustainability responses that require integrated thinking – because they interact with so many urban systems and processes. Section V considers the role of governance as a potential facilitator (or hindrance) at implementing integrated strategies for urban sustainability. Finally, in Section VI, we synthesise key findings and messages, before identifying research challenges and priorities for the future of urban integrated assessment.

Acknowledgements

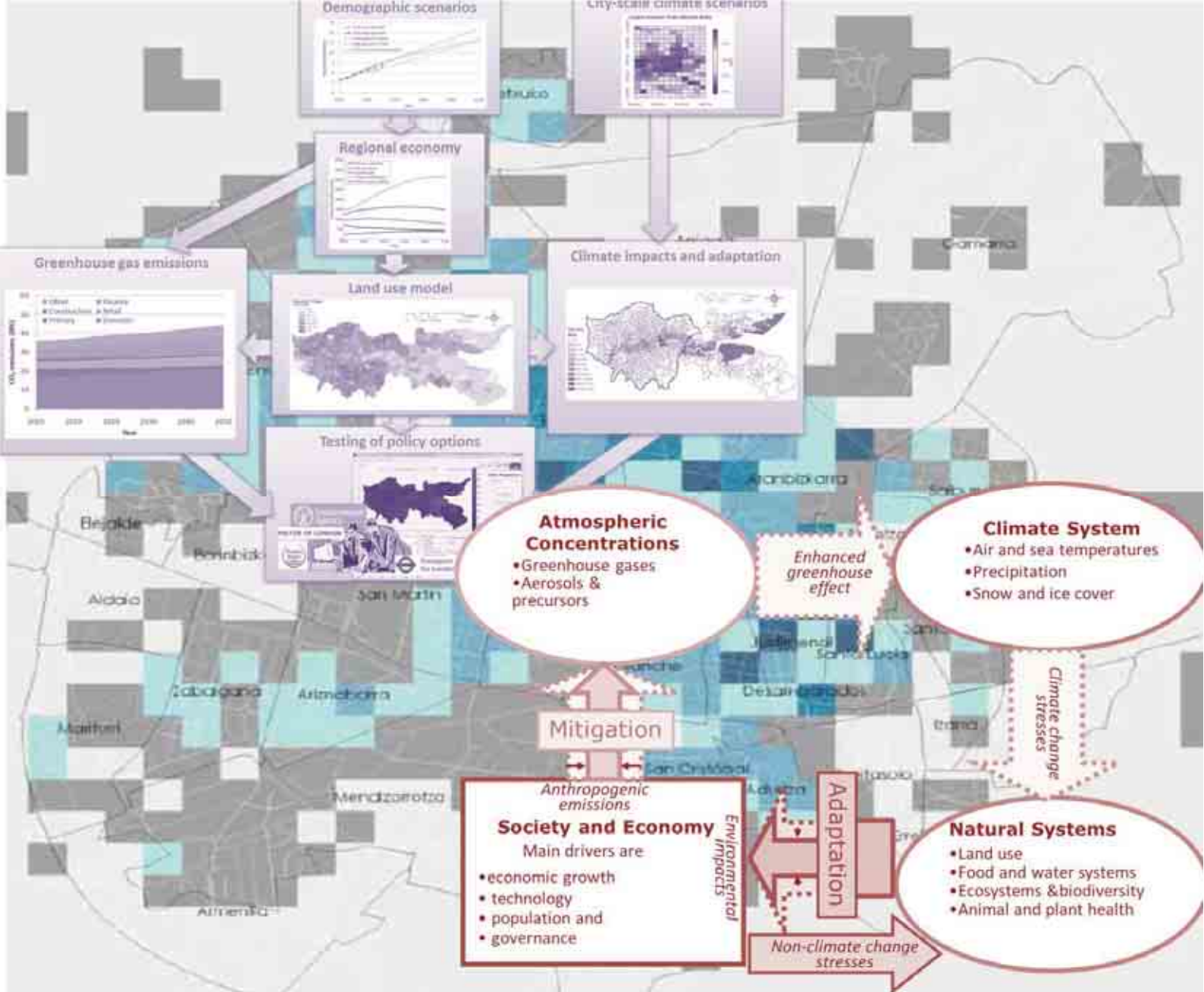
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A review and analysis of quantitative integrated environmental assessment methods for urban areas

Section II

A review and analysis of quantitative integrated environmental assessment methods for urban areas

Jonathan Köhler¹, Mika Ristimäki², Vincent Viguié³, Efren Felieu⁴, Dan Zachary⁵, Gábor Dombay⁶, Dragutin Mihailović⁷, Kestutis Zaleckis⁸, Gerald Leindecker⁹, Dolce Coelho¹⁰, Lena Halounova¹¹, Vladimir Holubec¹¹, Engin Nurlu¹², Ulrich Leopold⁵, Eduardo Olazabal⁴, Richard Dawson¹³

¹ *Fraunhofer-Institut für System- und Innovationsforschung ISI; Breslauer Strasse 48, 76139 Karlsruhe, Germany; j.koehler@isi.fraunhofer.de*

² *SYKE, Helsinki, Finland*

³ *CIREN, Nogent-Sur-marne, Paris, France*

⁴ *Tecnalia, Bilbao, Spain*

⁵ *CRP Henri Tudor, Luxembourg*

⁶ *SZIE Ybl University, Hungary*

⁷ *University of Novi Sad, Novi Sad, Serbia*

⁸ *University of Kaunas, Lithuania*

⁹ *Institute für Analytische Strukturentwicklungsplanung, Hinterschweigerstr. 2, 4600 Wels, Austria*

¹⁰ *Polytechnic Institute of Coimbra, ISEC, Coimbra, Portugal*

¹¹ *Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic*

¹² *Ege University, Faculty of Agriculture, Dept. of Landscape Architecture, Izmir, Turkey*

¹³ *School of Civil Engineering & Geosciences, Newcastle University, United Kingdom*

Highlights

- The WG1 cases show that integrated sustainability assessment at the city/urban area level are being used to assess a wide range of sustainability issues.
- The most serious difficulty is giving the modelling an effective role in the decision making process, because the assessment may take some time to perform and the results are complicated and therefore difficult to communicate.
- Integrated assessments usually have spatially explicit analysis and data.
- They use a wide range of methods from integrated models to non-model indicator calculation from data.
- Integrated assessments are more complex than single disciplinary assessments, but data is becoming cheaper and cheaper to collect and computational power is also readily available.
- Data availability is in our opinion not a fundamental problem. While detailed data enables a more accurate and possibly convincing analysis, simple data can enable a simple integrated assessment. If e.g. a small, poor city does not have much resources, it is still possible to compare maps of different aspects and their spatial variation over the city e.g. population density and air quality. A simple integrated assessment can still help to assess policies and links between perspectives and whether qualitative conclusions of complex assessments are generalizable or not. The cases summarised here show, however, that even in smaller European cities, detailed data is often available, particularly for spatial analysis.

1 Introduction

This report provides a summary of case studies on integrated assessments of cities compiled for the TU0902 COST action: integrated assessment technologies to support the sustainable development of urban areas. TU0902 has a working group (WG1) assessing methodologies for integrated assessment methodologies applied to cities. A definition of integrated assessment is provided by Rotmans (2006):

“Sustainable development has become an overarching policy target for the global policy arena. However, the international policy making process and that of the individual countries remains largely sectoral in nature: a wide spectrum of international policies pursues narrow sectoral concerns and do not contribute fully enough to the achievement of broader sustainability targets.what is really needed is a cross-sectoral approach to assessing sustainable development at an even higher, much more strategic level: Integrated Sustainability Assessment (ISA). ISA involves a long-term, comprehensive assessment of international and national policy programmes against sustainability targets and criteria.

In order to perform ISA.....new assessment tools and methods are needed which are rooted in a new paradigm. Sustainable development is a complex, multi-dimensional phenomenon, with a breadth and depth that cannot be fully covered by the current portfolio of ISA tools. We therefore need a new generation of ISA tools, in particular modelling tools that can (semi-)quantitatively assess the multiple dimensions of sustainable development, in terms of multiple scales, multiple domains and multiple generations.”

This is a reflection of the idea of sustainability defined in the Brundtland report (WCED, 1989): *“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*.

Integrated Assessment Models (IAMs) are complicated to design and to use, and this report will examine how such tools have been used in eleven urban areas: Paris, Helsinki, Vitoria-Gasteiz, Luxembourg, Debrecen, Novi Sad, London, Kaunas, Linz, Coimbra, a survey of Czech cities and Izmir. These assessments illustrate a wide range of objectives and methodologies. Case study summaries have been produced to a common report structure, defining the scope of the assessment, topic, what is modelled, methods, data sources, links with stakeholders and results. An additional quantitative multidisciplinary environmental model is also reported in Box III-2 of this volume.

The comparison between these IAMs led to some interesting conclusions: despite the diversity of IAMs studied, significant commonalities are observed, both in approaches and in conclusions. Some other characteristics are on the contrary different for almost all of IAMs listed here. This report highlights also implications for governance issues, using a dialogue with WG4 on Governance, and what has been the impact on decision making.

2 Integrated assessment modelling for Cities

Integrated assessment modelling, especially for cities, can be a very powerful tool to analyze and design strategies aiming at a local sustainable development. However, this kind of approach can be difficult to design and to use.

2.1 General methodological considerations

The concept of sustainability assessment is inherently interdisciplinary. This is because it has the objective of supporting decision making in society and therefore has to address social goals through social criteria, while the phenomena being studied are impacts in the ecosystem i.e. phenomena in the natural sciences domain. The most common social criterion is that of cost, following the tradition of Cost-Benefit Analysis, which has the objective of ranking alternative options for projects with public as well as private benefits. This approach performs the ranking by identifying the various impacts and associating monetary values to them. This requires that public goods such as environmental changes and human safety are also monetized. This approach is also used in many integrated assessment exercises. It has the benefit of producing a clear, single ranking. However, it also has the problem that the monetization of non-traded, public ‘goods’ such as climate change is very difficult, with values strongly dependent on the valuation method used. The alternative approach, from public economics is to allow more than one metric of comparison and identify so-called ‘Pareto improvements’, in which one action is ranked higher than a second action if the first action is at least as good as the second for all metrics and better in at least one metric. This method has the problem that different options where one option has a higher value in one of the metrics and the other option has a higher value in another metric cannot be compared. An extension of this is multi-criteria analysis, where the different metrics are assigned weights. The weights can then be selected by the analyst or by stakeholders.

This means that another possible approach is to show results for the different metrics for all options, as an input into a decision making process, but without stating a final judgement over which option is ‘best’. This is illustrated in Figure 2.1 from the Vitoria-Gasteiz case. The figure shows four sets of general criteria which are considered necessary for an efficient urban system: compactness and functionality, complexity, efficiency and social stability. These general criteria are then measured through four separate sets of indicators.

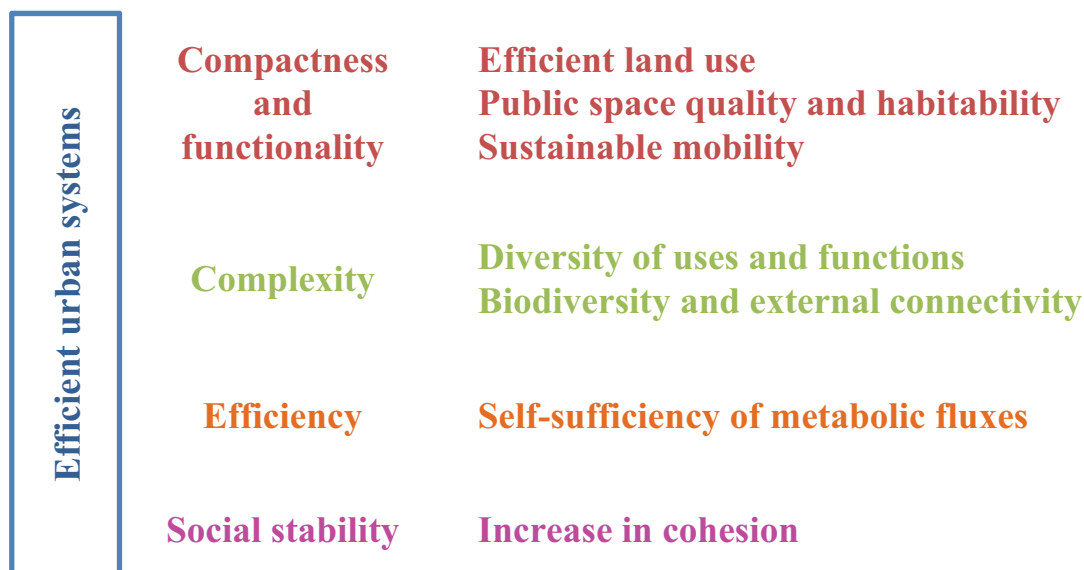


Figure 2.1 Conceptualised efficient urban system model (adapted from: Miguel Virizuela and Andrés Alonso. Vitoria-Gasteiz City Council.).

Overall, therefore, an integrated environmental assessment requires both social and natural science components, with a presentation of results for input into a social decision process. An implication is that even for a numerical modelling exercise in this field of sustainability assessment, explicit account has to be taken of the relationship with the stakeholders in the decision making process.

A further issue is that of multiple scales of assessment that have to be addressed. While the geographical scale is regional, it may also require local scale analysis and an assessment of compatibility with national scale plans. This is also true of governance, where national and local governance issues have to be addressed as well as the city/regional scale. These different scales also then result in different timescales of analysis.

2.2 Benefits of IAMs

Numerical models are simply a quantification and an automation of logical processes. They can be used in cases where qualitative reasoning becomes too complex to be adequately carried out. IAMs, i.e. numerical models which link social systems to natural/physical systems are similarly useful when the interactions between these two systems become too complex. In cities, this is especially the case when trying to identify multilevel governance challenges and find tradeoffs between different aspects of the city system and the related social and planning objectives.

The approach of integrated assessment of sustainability also provides another and source of scientific evidence for policy making. Evidence based policymaking has been one of the modern themes in policy practice, first emphasized in the UK in the 1990s (Davis et al., 2000). The multi-disciplinary approach of integrated assessment can contribute new evidence through the links between different aspects of sustainability and as discussed above, identifying trade-offs and synergies that a single disciplinary approach will miss. An example of links between physical and social systems is shown in Figure 2.2, which represents the system structure of the London Urban integrated Assessment Facility.

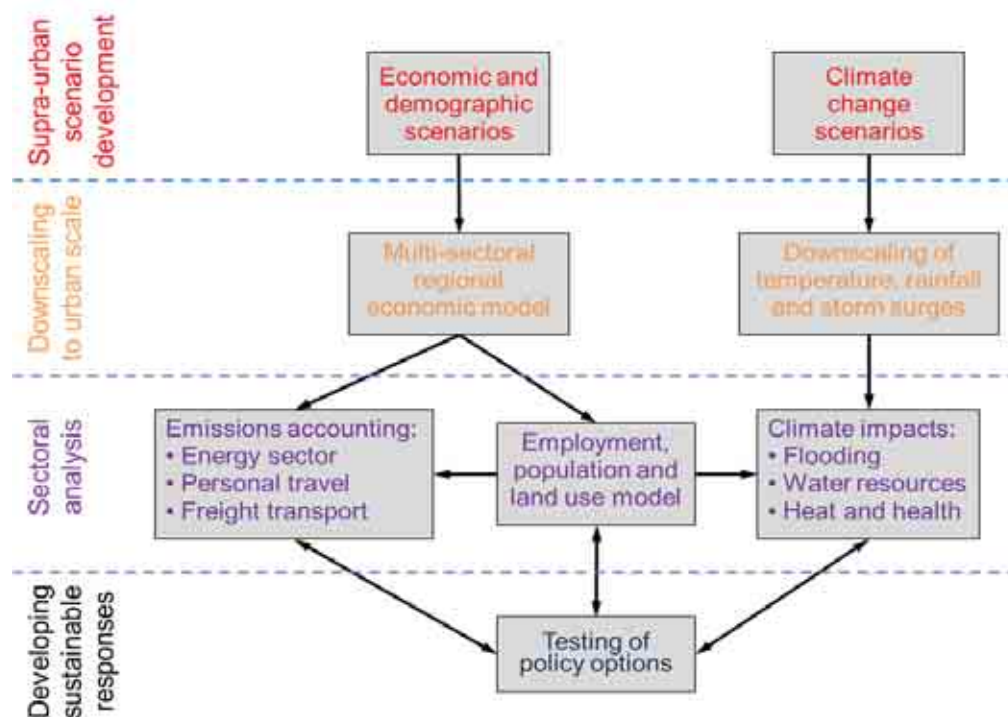


Figure 2.2 Overview of the Urban Integrated Assessment Facility applied in London (U.K.).

In the UIAF, socio-economic and climate scenarios provide the context for the analysis. A process of down-scaling generates climate scenarios at the city scale as well as economic and demographic scenarios for the urban area which provide the boundary conditions for the city scale analysis, in this case London. A spatial interaction module provides high resolution spatial scenarios of population and land use that form the basis for analysis of carbon dioxide emissions and vulnerability to climate impacts under a wide range of scenarios of climate, socio-economic and technological change. The UIAF can be used to test the effectiveness of a wide range of mitigation and adaption policies, including land use planning, modifications to the transport systems, changing energy technologies and measures to reduce climate risks under different scenarios.

2.3 Limitations of integrated assessment models

The main limitation of integrated assessment is that it is more complex than single disciplinary approaches. This means that it is more difficult to collect data, requires an extra theoretical basis for the links between the different perspectives and tends to lead to more complicated modelling structures. This creates several problems.

First, developing such model comes at a high cost in terms of calibration and design. Collecting data, coding the simulation software, understanding all theoretical framework used, linking scientific outputs with decision maker all require time, money and competences. The opportunity of developing such approaches has therefore to be well balanced against the costs.

Second, given the complexity of integrated assessment models, it is not easy to make them accepted. The wide range of methods adds to this problem. There is no single modelling structure that can be generally accepted for all assessments, which opens the field for a large number of different approaches which may then be difficult to compare and hence to judge for their scientific quality. IAM models are used to integrate and process knowledge from different parts of the system, and in doing so allow us to test system understanding and generate hypotheses about how the system will respond to particular actions via virtual experiments. However, as we try to make our models more “realistic”, the more parameters and processes we include. The price we have to pay for this attempt is the fact that with increased model complexity we are less able to manage and understand model behaviour. As a result, the ability of a model to simulate complex dynamics is no more an absolute value in itself, rather a relative one. Namely, we need enough complexity to realistically model a process, but not so much that we ourselves cannot handle. Thus, from a practitioner’s standpoint, this sentence can be rephrased. Often in the modelling community complexity is seen as somehow related to a model architecture, that is, there is a notion of some sort of monotonic relation between complexity and model “size”, where size accounts roughly for dimensionality, connectivity, number of interacting processes, etc. as: “how complex a model do I need to use in order to study this problem with this data set?”. However, it is possible that the definition of the complexity of an IAM model as the statistical complexity of the output it produces could be an informative approach. This definition of the model complexity better captures the difficulty faced by a user in managing and understanding the behaviour of an IAM model than measures based on a model “size”.

Finally, on the contrary, caution should be taken not to have IAMs conclusions blankly accepted by stakeholders. Scientists cannot simply build the models and write the conclusions, they have to explain them to stakeholders and participate to some extent to the decision-making process to make sure no misunderstanding occurs. Like all modelling, IAMS are never complete and can never include all components. This is especially true for the social system modelling component, which,

conversely to the physical/natural system component, can generally hardly be validated against reality. Stakeholders have to understand these limits, without at the same time consider that model conclusions do not give any meaningful results at all. Explaining what is this domain of validity of the model is an important role that experts who developed the models have to play. However, this is all the more difficult when the model is complex.

2.4 Uncertainties and scale in integrated assessment models

Integrated assessment models typically combine several models to account for environmental, social and economic aspects at different temporal and spatial scales. The uncertainties associated with these model predictions are rarely taken into account in the decision process. These decisions are important, because they may affect the population's health or cause substantial environmental impacts, e.g. health problems due to air pollution, drinking water pollution due to industrial or agricultural practise, floods due to elimination of potential infiltration areas. The sources of uncertainty arise from input data, model parameters and model structures.

Uncertainty is also affected by the change of scale that is often induced by the integration of different models. Often, the policy or decision scales differ from the scales for which the models were originally developed. The change of scale in integrated assessment modelling approaches involves up- and downscaling of model inputs, model parameters and adaptations of model equations in order to make predictions at the policy scales. These changes of scale and associated errors often receive too little attention, which may affect the quality of model results and thus their usability in spatial and urban planning.

Uncertainty propagation across changes of spatial and temporal scales in integrated assessment models have been recently addressed but methodologies and tools still have to be developed to assess their impact in a meaningful way for decision making.

Another problem is the comparison of model results with independent measurements occurring at different scales (i.e. supports), e.g. area (block) predictions versus point measurements. Point observations cannot be compared directly with block predictions as they occur at different scales. Spatial and temporal aggregation techniques can help to account for change-of-support for aggregation and disaggregation. We now analyze how IAMs and indicator assessments have been used and designed in a few case studies, and how (or whether) these benefits have been utilized and these limits overcome.

3 Scopes and Methodologies of the case studies

Because an IA and modelling in an IAM combines approaches, there is a very large set of possible topics and approaches, covering different combinations of scientific disciplines and methods. There are however relatively few examples of this approach applied to the regional/city level. This report brings together examples from twelve urban areas: Paris, Helsinki, Vitoria-Gasteiz, Luxembourg, Debrecen, Novi Sad, London, Kaunas, Linz, Coimbra, a survey of Czech cities and Izmir. These examples are very different in terms of scope, approaches and conclusions.

3.1 Summary of the cases

The eleven cases are summarized in Table 2.1, with further details of each case in the online COST Action archive (<http://www.ncl.ac.uk/ceser/researchprogramme/costactiontu0902/>). It should be

emphasized that these cases are not a comprehensive overview of integrated assessments that have been applied to cities. Rather, they are a selection of the topics and methods that have been applied in the EU urban context.

The studies address a range of scopes, covering different environmental impacts: pollution, heat waves, water quality, flood risk, biodiversity, local air quality, greenhouse gas emissions, natural amenities and energy demand. City structure or morphology is addressed by the cases for Paris, Helsinki, Vitoria, Debrecen, London, Kaunas, Linz, the Czech survey and Izmir. Transport patterns and transport planning is addressed by the Paris, Helsinki, Debrecen and London cases. The Luxembourg case assesses energy use to generate sectoral emissions and analyse air quality and the Coimbra case also considers energy while the Novi Sad case undertakes a statistical analysis of air quality and climate data to assess indicators for public health such as UV exposure.

The cases also use a range of analysis approaches. The Paris, London and Linz cases combine several simulation models to generate scenarios. The Izmir case uses a cellular automata simulation. The Helsinki and Kaunas cases are based on an analysis of spatial data, but do not undertake simulations. The Vitoria case is also data analysis based, but uses spatially differentiated data from scenarios to calculate a set of environmental indicators. The Czech survey also uses an indicator approach. The Novi-Sad case also uses an indicator approach. It uses time series estimation of climate data to identify time series models of environmental indicators (heat and wind chill indices). The Debrecen case uses a transport network analysis to generate scenarios of traffic flows and the associated local emissions. The Luxembourg case uses the MARKAL dynamic cost-minimisation structure for energy technology costs and emissions. The Coimbra case uses a multi-criteria analysis to assess different energy measures.

In terms of modelling of natural science phenomena, the range of approaches used covers: simulation models, statistical data analysis, expert knowledge for parameter assessment or simple linear coefficients (e.g. for conversion of energy use to emissions). In terms of social science analysis, the Paris, Helsinki, Vitoria, Debrecen London and Linz cases all consider or generate data on behaviour/choices, while the Paris, Luxembourg and London cases all include the analysis of economic sectors. Two approaches in general to the use of scenarios can be identified. Scenario information is either completely exogenous to the analysis, in the cases of Helsinki, Vitoria, Debrecen, Novi Sad and Kaunas, or partially endogenous. A partially endogenous model uses the model structure and exogenous information on future parameter values for some variables to develop further scenario information, as undertaken in the Paris, Luxembourg, London and Linz cases. These can be described as computer simulation models. There are many possibilities for endogenous variables. One important driver of future patterns of development and emissions is population size and (spatial) distribution.

There is a difference between IAMs where population evolution is supply-driven (i.e. number of inhabitants given by the number of new buildings that it is possible to build) and IAMs where it is demand-driven (i.e. evolution of number of inhabitants is exogenous). The Kaunas case does not include an emissions model, but assesses the spatial structure of ‘green’ areas in the city.

The cases all have close links with stakeholders. They can be seen as tools for providing ‘expert advice’, developed using data from stakeholder sources and using scenarios developed by stakeholders as inputs.

3.2 Brief description of each case

3.2.1 Paris

The Paris case uses a regional model structure to assess transport-related GHG emissions, land-use changes, heat island effect and heat waves impacts. Transport price and income scenarios are computed by Imaclim-R (a hybrid model which combines a macroeconomic approach with local transport engineering data) and NEDUM, a land-use-transport interaction model, is used for land-use change projections. Climate modelling uses a general climate model (ARPEGE-Climat) and a land surface model (TEB-SURFEX).

3.2.2 Helsinki-Lahti

This case investigates the main relationships between urban form, travel behaviour and CO₂ emissions. It considers how to use integrated analyses in real planning in different planning scales (master, general and regional plan) for three cases: peri-urbanisation in Helsinki metropolitan regions, measuring urban accessibility in transit oriented for the Kerava sub-centre in Helsinki-Lahti, Helsinki-Tampere railway corridor and the assessment of Lahti general development plan 2030 using integrated analyses. It uses transport behaviour data with GIS analysis of inhabitants' accessibility to various resources and amenities.

3.2.3 Vitoria

This case uses the Vitoria development master plan to assess the actual state of urban sustainability in Vitoria-Gasteiz and the future state of urban sustainability in Vitoria-Gasteiz under the current development and the approved plans. It calculates indicators of sustainability from city data. Thus the assessment does not use a simulation model, but calculates 50 sustainability indicators for land use, population growth, accessibility, green zones, CO₂ emissions, waste, noise, energy use and production and food self-sufficiency (Ayuntamiento de Vitoria-Gasteiz, 2010).

3.2.4 Luxembourg

The Luxembourg Energy Air Quality (LEAQ) is an Integrated Assessment Model designed for solving combined energy-use and air quality impact problems and can be used for both energy and air quality policy support in the Grand-Duchy of Luxembourg. The model provides a way to explore lowest cost energy technologies that can meet energy demands with environmental constraints (air quality constraints, such as legislative ozone levels). The model combines the ETEM model and an air quality model, AUSTAL2000-AYLTP, which is a transport model combined with an ozone calculator. ETEM belongs to the family of the market allocation models (MARKAL) and solves the sectoral energy demands (e.g. transportation, industry, space heating) given the energy devices (e.g. vehicles, houses). The models are coupled via decision variables (primary emission levels – NOX). One of the outputs of the model is the sectoral emissions of CO₂, NOX and VOC in tons per year, the latter two can then be used for air quality simulation work.

3.2.5 Debrecen

The Debrecen case assesses the actual state of urban traffic in Debrecen. It identifies the major strategies to create sustainable urban traffic conditions. The case uses a transport network model which includes the transport infrastructure with junctions, road structure, traffic control, parking, public transport, pedestrian and bicycle transport. Traffic modelling uses the CUBE-TRIPS software.

The model comprises three major components: spatial model, a transport network model (road and public transport) and a traffic flow matrix. By the use of modelling different scenarios are evaluated.

The model has been used to provide inputs to the city strategy for sustainable urban traffic development. This has the goals: protection of the city centre, development of a traffic network with the lowest environmental impact, encouraging environmentally friendly ways of transport, inhibiting car traffic, providing transport according to the function of the area and improving the accessibility of commercial and industrial areas.

3.2.6 Novi Sad

This case looks at the physical and social processes driving long run changes in Novi Sad particularly driven by the economic transition. It considers how quickly growing cities can change their physical, chemical and social environment and how a city can grow while reducing vulnerability to climate change. An integrated assessment system is being developed. At the current stage of development, impacts on public health are assessed through: (i) changes in UV radiation (the NEOPLANTA UV radiation and UV index, which was run for the period 2002-2011) and (ii) calculation of simplified bio-meteorological indices (heat index and wind chill index for the period 1992-2008). The Heat Index as a measure of how hot it feels when observed ambient temperature and humidity are combined and the Wind Chill Index presents the chilling effect of the wind in combination with a low temperature. It uses regional climate scenarios generated by the EtaPOM regional model [1] on the basis A1B scenario (the runs were done with projections for 2050): (i) to represent the urban heat island effect and influence of spatial patterns of development on the risk from heat waves and (ii) to use a rainfall scenario for the Danube and surrounding channels and then combine that with catchment hydrology models and simulation of the water resource management system.

3.2.7 London

The London case developed a combined modelling system. The following areas are addressed by the UIAF for London: Economics, Land Use patterns for London and the Thames gateway to 2100, CO₂ emissions from energy use, passenger transport and freight transport. The following climate impacts are assessed: Heat Waves: Use of the Hadley Centre Regional Climate Model to represent the urban heat island effect. Influence of spatial patterns of development on the risk from heat waves. Droughts for the Thames and Lee catchments, a model of flooding in the tidal Thames floodplain, has been used to simulate the effects of sea level rise and changing flows in the river Thames. This has been combined with our simulations of land use changes to develop simulations of flooding risk for the Thames river basin and the Thames Gateway.

3.2.8 Kaunas

This case evaluated the potential of urban structures in Kaunas as part of newly prepared Kaunas Master Plan in 2011. It considered how the fractal index of the urban structure could be used for evaluation of urban potential. The fractal index can be used for qualitative evaluation of urban territories as well (i.e. evaluation of functional possibilities of urban form as urban potential). To evaluate urban potential, fractal indices of the four main constituent components of urban structure were calculated: buildings, streets, greenery and public spaces. The data sources were a GIS-database of Kaunas, photographs and information on present situation from prepared Kaunas Master plan.

3.2.9 Linz

The Linz case in Austria (Solar City) is a model of creating a low carbon environment in a new planning area. The city planning lay out was done according to solar principles. Building design and the used of material was planned according to thermal principles and to minimize running costs. Solar City was designed as new urban development for approximately 5000 inhabitants in close proximity to the regional capital of Linz. All buildings were done according to low energy standards and some housing units were duplicated in passive house standard as well. The idea of a living lab was introduced to measure and monitor the performance of buildings in use. The start for realization was to have common standards in energy figures such as hot water solar panels and prime energy figure of below 44 kWh/ (m²a). This energy performance was also applied towards public buildings (schools, kindergartens and similar facilities).. By the use of energy performance calculations the decision making process was effected. The living-lab data is constantly monitored and analyzed.

3.2.10 Coimbra

This assessment uses an urban energy planning model, based on multi-criteria analysis, can be used to facilitate decision making in sustainable energy planning problems in an urban context. The methodology is applied to energy and environmental management, particularly by enhancing energy efficiency and the exploitation of local resources (renewable energy), containing a coherent set of measures covering the key sectors of activity: not only the buildings and facilities that are managed by the local authority, but also the main sectors of activity in the territory of the local authority: residential sector, services sector (public and private), seeking a path to sustainable urban development.

The categories of actions can be assessed by type (e.g. energy-efficient technology replacement, energy-efficient renovation of existing buildings and renewable energy systems), as presented in or by sector (e. g. residential, private services and public services/municipal). The model has been used in the development of the Sustainable Energy Action Plan of the municipality of Coimbra in the framework of the Covenant of Mayors.

3.2.11 Cities in the Czech Republic

The project was focused on a detailed evaluation of relations between quality of life and present behaviour of the human society characterized by selected spatial and non-spatial indicators. The relations were analyzed in 50 cities in the Czech Republic in last forty years. Twenty years covered the period during the communist regime and the second half of a transforming period to the democratic regime. Analyzing traffic of incoming (MRTI) and in-city (ARTI) traffic intensity showed different dependences. Analyses of all cities presents a general influence, however, each city is individual and should be analyzed individually There are more indicators which have an important influence to the road traffic in all cities and therefore have to always be taken into account. Reliability of extrapolation of developments of individual cities is far substantially higher even for the whole period than a general trend for all cities. Economic growth power has a high correlation coefficient for all available indicators. The different growth is the main difference between both political periods.

3.2.12 Izmir

The aim of this study was to simulate the urban growth in the city of Izmir, among the mega cities that have experienced rapid land use change because of the diversity of economic activities,

population growth and urbanization. The SLEUTH urban cellular automata model was used to develop future urbanization scenarios and future urban growth was projected out to 2040. The dataset consists of slope, land use, excluded layers, urban extents, transportation, and hillshade. In order to predict the urban growth, two future urban growth scenarios were developed based on current trends, and managed growth with protection.

The statistical simulation results for alternative scenarios indicated higher dispersed development patterns in urban areas than in agricultural, forests and semi natural areas from 2009 to 2040 for the study area. While a significant growth rate was observed in urban areas in current trends scenario, the growth rates for the managed growth with protection scenario were reduced due to the higher levels of protection.

Table 2.1 Summary of case study main characteristics.

City	Time horizon	Scope (what is modelled?)	Socio-economic modelling or scenarios?	Physical modelling?	Link with stakeholders
Paris (France)	2100	City expansion, transport-related GHG emissions, Heat island effect and heat waves impacts.	Expert-designed demographic scenarios; Transport and income scenarios computed by Imacim-R (hybrid model which combines a macroeconomic approach with district-engineers views), land-use transport interaction model used for land-use change projections.	Climate model (Arpege-climat), Urban climate model (TEB-SURFEX)	Close collaboration with Paris and Toulouse municipality, as well as with the French ministry of environment.
Helsinki/Lahti (Finland)	2025	GIS analysis of inhabitants' accessibility to various resources and amenities.	New developments are given by existing urban master plan; Population evolution is supply-driven.	No	Development of regional transport plan for regional authorities.
Vitoria-Gasteiz (Spain)	2020, 2050	Indicators of sustainability obtained by the modelling of various variables (land use, accessibility, energy use, noise, green zone etc.).	New developments are given by existing urban master plan; Population evolution is supply-driven.	No	Close collaboration with Vitoria-Gasteiz City Council.
Luxembourg	2030	Air Quality: coupled energy and air model.	Energy demand follows business as usual scenario; energy supply and emissions levels are then modelled through energy-mix optimization (ETEM model, part of MARKAL models family).	Air quality model	Model to support decision making.
Debrecen (Hungary)	2012	Traffic modelling for sustainable urban traffic development and emissions.	Traffic modelling for 6 expert-designed scenarios.	Coefficients to link congestion with pollutant emissions	Input to transport planning process in Debrecen.
Novi Sad (Serbia)	2050	Air quality and biodiversity impact	Econometric modelling of time series of air quality.	Air quality model	Model to support decision making.
London (U.K.)	2100	A very wide range of mitigation and adaption policies	Regional economics using Input-Output model, Geographical modelling of land use patterns, Transport activity and emissions.	Global and regional climate models (heat island effect), hydrology and flooding models,	Close collaboration with stakeholders in London, including the Greater London Authority, Transport for London, the Environment Agency and Thames Water.
Kaunas (Lithuania)	2012	Spatial Structure/morphology using a fractal	Not applicable.	Fractal structure of the buildings,	Used for development of Kaunas development master plan.

			analysis, to assess the sustainability of the city in terms of its spatial structure (compactness, relative availability of green spaces).		roads, green areas	
Linz (Austria)	1999-2012	City expansion;	Energy demand and emissions levels are modelled through energy-mix optimisation calculation models to obtain guidelines for new town development.		Early application of prime energy demand of buildings in relation to material, construction methods and street lay out	Model to support decision making ; Used for development of solar city master plan and building parameters.
Coimbra (Portugal)	2013 - -	Assessment of energy efficiency actions within urban energy systems by type or by sector according to economic, technological, social and environmental criteria through the application of an MCDA model.	Results can be obtained for energy efficiency actions including the decision maker's preferences and/or including constraints to the classification.	No		Involvement of the main stakeholders: local authorities; energy consumers; energy agency; technical officers; manufacturers of end-use appliances; local producers; energy companies; transportation companies.
A number of cities in the Czech Republic	1968 - 2010	Relations between quality of life and present society through indicators: Functional typology of urban areas: Urban, agriculture, forest and water surface areas and other function areas, environment, social and economic development.	Correlation coefficients, Multiple Linear Regression.	No		Project for Czech Ministry of Education.
Izmir (Turkey)	1984 - 2040	Future urbanization scenarios and future urban growth: slope, land use, excluded layers, urban extents, transportation, and hill shade.	Cellular automata simulation.		Geographical structure: six categories of land use.	Project funded by the Scientific and Technological Research Council of Turkey.

4 Commonalities and differences

4.1 Disciplines/perspectives

In this set of nine cases of urban integrated assessment, there are two predominant themes: spatial structure and environmental sustainability or performance. This can also be seen in the main questions addressed, which are mostly the same:

- What is the most sustainable morphology for a city or urban area - densification vs new town development e.g. what should be the balance between poly-centric and monocentric development?
- What are the impacts or benefits of (green/open) spaces?

Firstly, all assessments have geographically based data/analysis, with mapping of geospatial patterns of different variables. While there are some analyses which sum e.g. economic activity in a sector or greenhouse gas emissions over the whole of a city/urban area, in the case of integrated assessments, there is always some spatial structure used either to generate the data or to interpret the results. This is a feature of all the cases and it is also a feature of all urban integrated assessments that we are aware of (e.g. Ravetz, 2000).

One reason behind that is the fact that there is a common concern in all the case studies : how the morphology of a city determines the sustainability of a city. In terms of the objectives of urban integrated assessment, this is the question of how town planning can change the morphology of a city to improve its environmental performance (e.g. Solar City, Linz). For example, greenhouse gas emissions and hence heat island effects from transport are generated by transport activity and transport activity is generated by the city morphology, as in the Paris and London cases. Another example is that in the Vitoria case, spatial data on land use is used to calculate an index of urban density and of compactness, while in the Kaunas case, GIS data on land use is used to calculate fractal parameters for the city. In the Linz case building data is used to model the energy consumption.

All the analyses aim at being multi-scale (local to whole city at least), i.e. try to link the behaviour of individuals to city level impacts. This is because of the local/regional nature of the problems being addressed. The concern is with local sustainability and policy making, which is concerned with local sources of emissions generated by local activity. This micro (in the language of economics) approach requires small scale information. Also, many of the issues, environmental or economic are spatially explicit at this level of analysis – which areas of a city have green spaces, where are the atmospheric pollution hot spots etc. Micro, spatially differentiated data is also necessary for assessing aggregated effects. This is illustrated in Figure 2.3, which shows an example of spatially differentiated data for economic impacts from flooding for the London case, as well as the aggregated result over the whole region

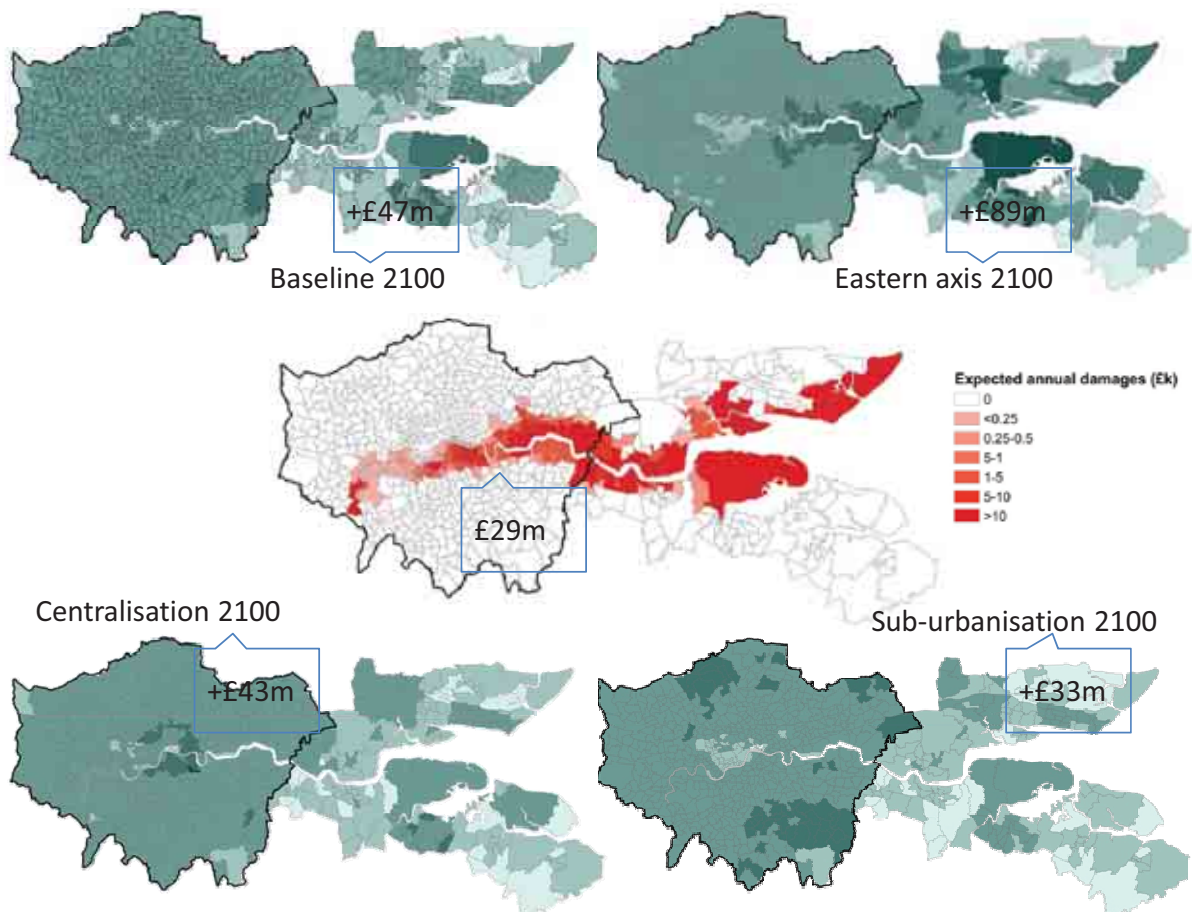


Figure 2.3 Assessment of expected annual damage from flood risk in London.

It is noticeable that in terms of the three pillars of sustainability (OECD, 2008) the environmental pillar is the main concern of these cases. The social and economic pillars of sustainability play a secondary role. This primary concern with environmental impacts is reflected in the topics of the cases. Most of them have atmospheric emissions as an output. Since these emissions are the consequence of human activity, there is necessarily a need for an integrated assessment, linking social and economic activity through technologies to natural science models for emissions. Environmental pillar is something which is routinely modelled (there is a large literature on environment modelling), whereas social pillar is something which is hard to model (generally, the literature is more qualitative). Economic development is somewhere in the middle. An interesting issue is whether IAM are useful only to study environmental pillar, or all three pillars.

The Kaunas case considers city morphology explicitly in terms of green space and compactness. These two aspects are both considered to be a direct measure of the environmental performance of a city, while green space is also considered to have an impact on quality of life. The Izmir case simulates the development of land use in six categories, as shown in Table 2.2 and Figure 2.4.

Table 2.2 Statistical simulation results for alternative scenarios in the Izmir case . for * Current Trends Scenario, and ** Managed Growth with Protection Scenario.

LAND USE	2009		2040 (*)		2040 (**)	
	Ha	%	Ha	%	Ha	%
Urban areas	24,707.00	27	40,751.19	43	35,276.31	37
Agricultural areas	3,059.00	3	1,115.91	1	1,812.51	2
Forests and semi natural areas	40,137.00	42	32,729.58	34	36,440.46	38
Maritime wetlands (saline & salt marshes)	4,284.00	4	4,189.95	4	4,211.91	4
Water bodies	3,138.00	3	3,137.34	3	3,137.34	3
Other land uses	20,555.00	21	13,956.03	15	15,001.47	16
TOTAL	95,880.00	100	95,880.00	100	95,880.00	100

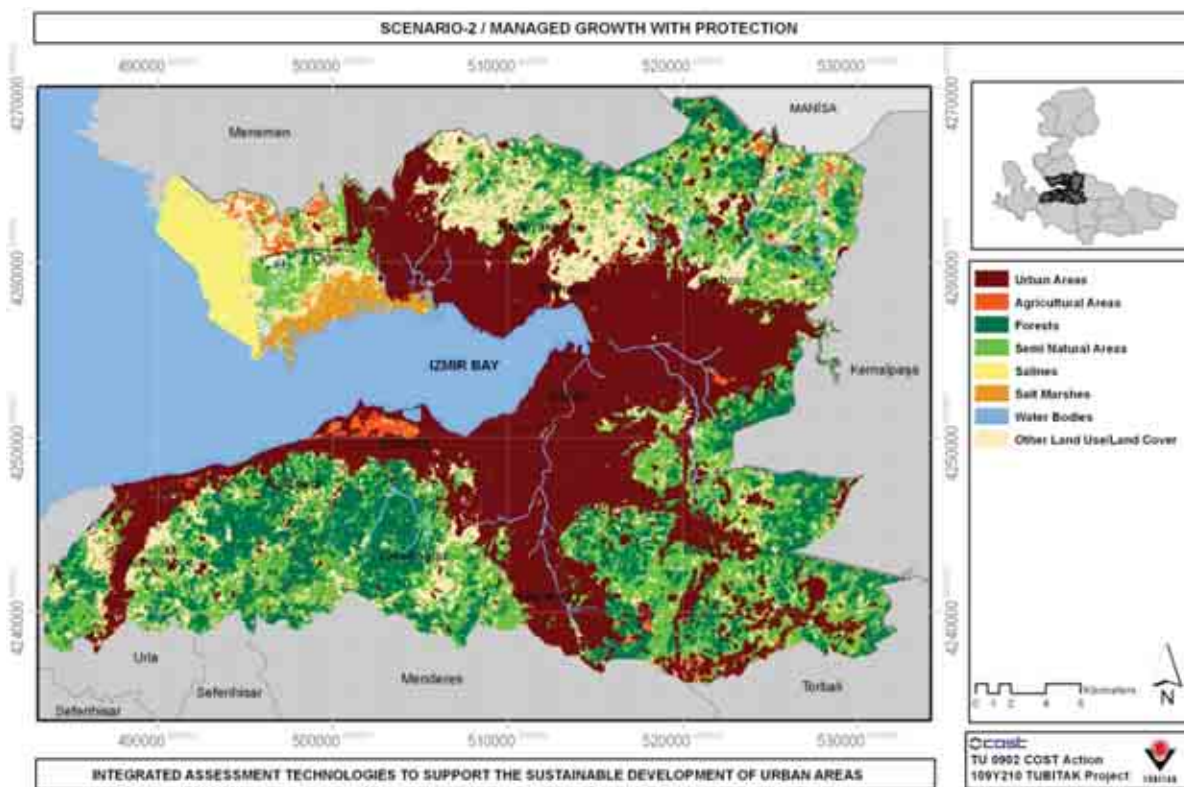


Figure 2.4 Managed growth with protection scenario prediction for 2040 in Izmir.

The Linz case uses energy performance figures of buildings with some consideration of private and public transport components.

The main aspect of social sustainability considered is that of accessibility in the transport related assessments in Helsinki/Lahti, Vitoria, Debrecen and London. The Vitoria case is an exception here in that it calculates six indicators of social cohesion including immigration, ageing, level of consumer equipment in households etc.

4.2 Variables in the analyses

One fundamental feature is that the cases all study evolution over time. This is because they are intended to contribute to planning decisions which are of their nature considering the future of the city. There are two approaches here. The Paris, Luxembourg and Solar City (Linz) are simulation modelling exercises which are fully dynamic. The Novi Sad case is also an analysis of time series data. The other cases are comparative, they assess the current urban structure and compare this to a scenario of a future structure. A fully dynamic analysis is more difficult to undertake, but it has the advantage that it can allow for the rate of change over time. Inertia is a main constraint when assessing significant urban policy. In particular, building stock can be long lived. In the UK, 57% of the housing stock was more than 44 years old, 21% was 90 years old or more (English Housing Survey, 2010). Infrastructure such as railways is also old on average, in the UK the main railway routes were all built by 1900.

Another fundamental question is the treatment of uncertainty. This is a particularly difficult problem in multi-disciplinary analyses with different types of variables with different measurement errors in calibration and different constraints on possible values. The most common approach is to regard the models as exploratory and generate a range of scenarios to explore different possible futures, which is in accordance with the literature on integrated assessment (e.g. IPCC, 2000). The London case does include statistical analysis of flood risk, thus incorporating uncertainty explicitly for some aspects of the modelling. A full uncertainty propagation analysis accounting for change of scale and its incorporation into the decision process would have been interesting to see. Adequate methods are still not available to visualise and communicate uncertainties in a meaningful way to decision makers so that more robust decision can be taken.

Most of the cases use population density as a variable as component of the spatial analysis. Population density is used in these cases in two ways. Firstly, it can be used as a variable to generate economic/social activity such as transport, employment or housing. Secondly, it can be used as an indicator of sustainability, based on the argument that a high population density reflects a compact urban morphology, which is less energy intensive than a dispersed urban structure. This is because a compact urban morphology can be assumed to have a high proportion of people living in flats or apartment buildings than individual houses or semi-detached housing. Apartments blocks have a lower heating requirement per household (English Housing Survey, 2010) and space heating is the largest component of household energy demand (English Housing Survey, 2010). Also, a compact urban morphology leads to shorter transport trip distances, reducing emissions for any given mode of transport and also favouring walking and cycling, which are by far the most sustainable means of transport for short trips. The concentration of people is more favourable to public transport modes, which are more energy efficient than motor cars (e.g. Köhler et al, 2009).

An interesting finding from this sample of cases is that economic variables are only included in five of the nine cases. Costs and process are driving variables in the dynamic modelling exercises in Paris, Luxembourg, Linz and London and the Vitoria case includes data on economic sectoral activities in recently urbanized areas.

4.3 Common Conclusions

The cases have a range of different disciplines and perspectives and it is therefore not possible to compare results in detail. One common aspect of the results that the models can identify trade-offs which would not be apparent without a multi-disciplinary view. This can be considered in more detail by taking a system approach to integrated assessment (Haxeltine et al., 2008), which is the approach of the London case. One of the aims of integrated assessment is to identify the links between the components of the social, economic and environmental sub-systems in the city system. The LEAQ model system (Figure 2.5) illustrates the combination of economic, environmental and policy variables.

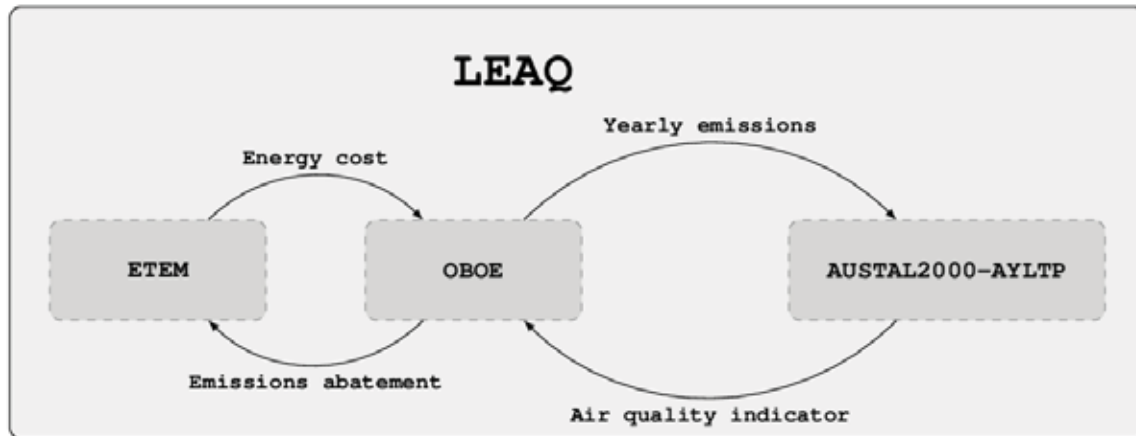


Figure 2.5 The Luxembourg Energy Air Quality (LEAQ).

LEAQ is an Integrated Assessment Model designed for solving combined energy-use and air quality impact problems and can be used for both energy and air quality policy support in the Grand-Duchy of Luxembourg. The model provides a way to explore lowest cost energy technologies that can fulfil useful energy demands with environmental constraints (air quality constraints, such as legislative ozone levels). The model combines the ETEM model and an air quality model, AUSTAL2000-AYLTP, which is a transport model combined with an efficient ozone calculator [Reis, 2012]. The models are coupled via decision variables (primary emission levels – NOX) and an optimization engine OBOE (Oracle Based Optimization Engine),

This can then identify trade-offs, but also complementarities between the system components in the form of negative and positive feedbacks. A trade-off in the Paris case is that the Green Belt effect (intended to restrict emissions increasing urban sprawl) increases the Urban Heat Island effect – an example of an interdisciplinary trade-off identified by an IA analysis. This process of urban sprawl is shown for the Paris case in Figure 2.6.

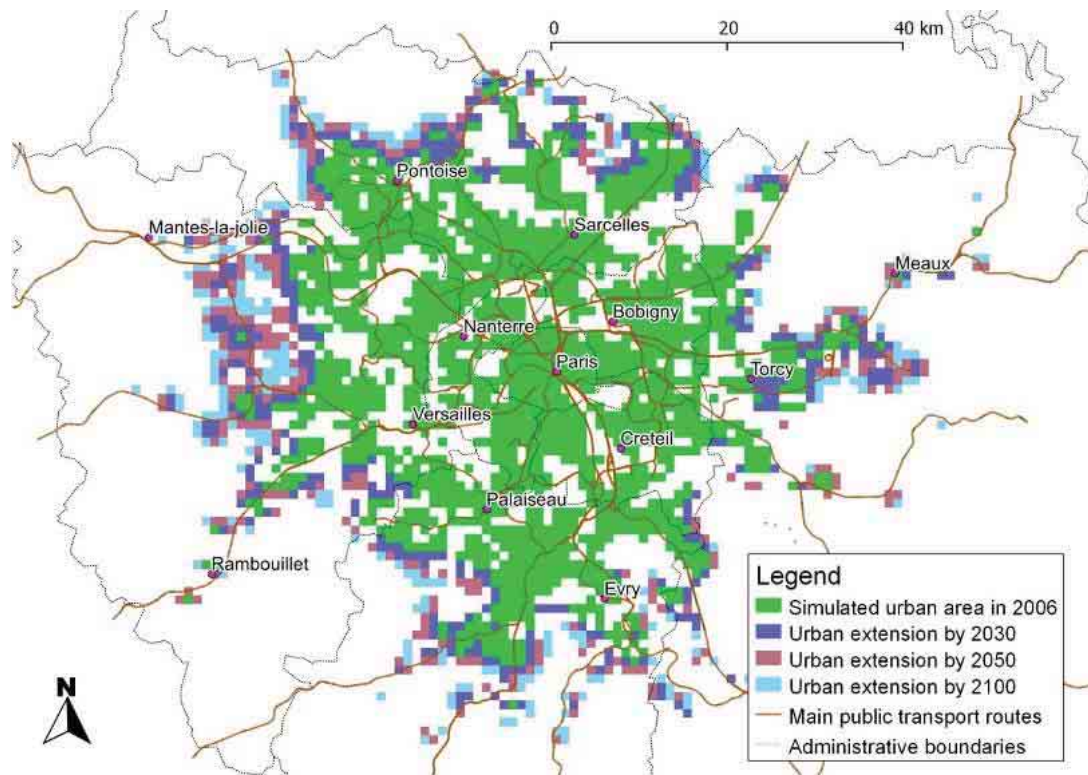


Figure 2.6 Example of Paris urban development scenario (used in VURCA project).

As discussed above, the cases are also multi-level analyses in that they look at city wide effects of local behaviour and structures. A good example is the Helsinki-Lahti case, where relationships between urban form and spatial structure are assessed across three scales, illustrated in Figure 2.7:

- Regional planning scale (Metropolitan region, city region and railway corridor)
- Master plan scale (City level),
- Detailed plan scale (City sub-centre in transit oriented district, TOD)

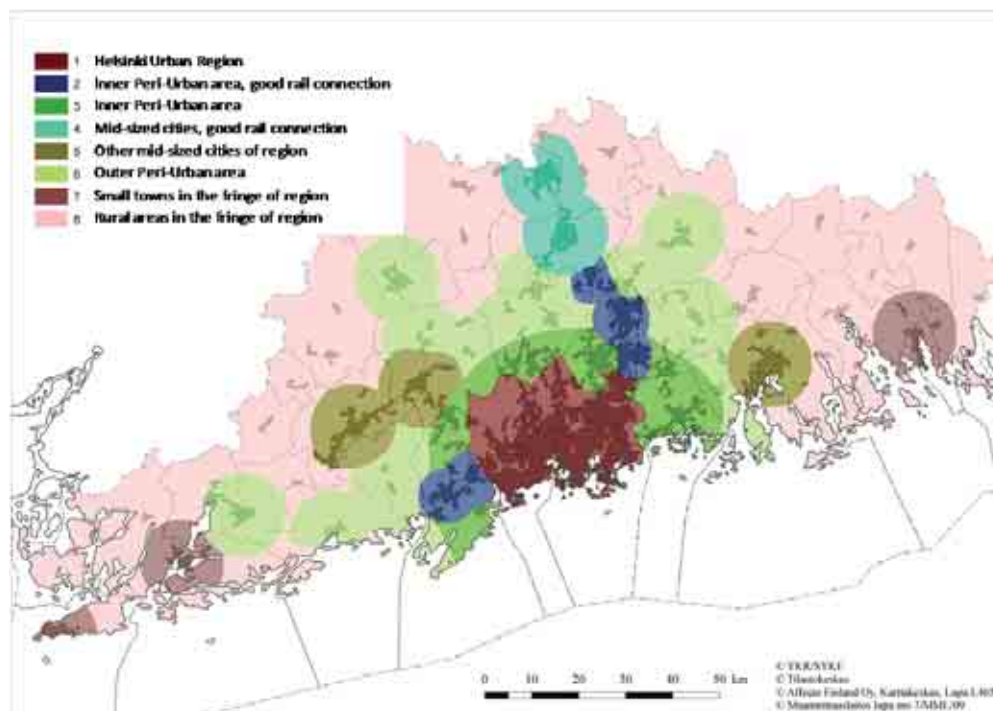


Figure 2.7 Area-based division of the Helsinki Metropolitan Region.

This type of approach enables the identification of trade-offs across different spatial and temporal scales, for example the need for more housing in the London region leading to proposals to site housing in a flood plain with the associated high flood risk for new housing. These decisions taken at a regional level will hence have implications at the local level. However, if the flood risk require large scale adaptation or flood defence measures, these will again be funded at the regional level, giving a feedback from local impacts back up to regional level decision making. For greenhouse gas effects, as in the Linz case, there is also the city/region interaction with global climate change, where city activities contribute to global emissions, while climate change will lead to potentially severe impacts requiring adaptation measures in the long run.

4.4 Differences and transferability issues

Although the discussion above has identified some commonalities in approach and methodological issues for integrated assessment of sustainability in cities, Table 2.1 shows that the nine cases cover a range of issues for sustainability and a wide range of methods for analysis. There is a mixture of optimisation (Luxembourg, Linz), dynamic simulation (Paris, London) and transport network (Debrecen, London) models and non-model assessment structures (Helsinki-Lahti travel and transport network data analysis, Vitoria indicator approach, Kaunas fractal analysis).

This raises the question of why the cases are so disparate. We argue that this is not due to geographical or political context. Although the cases cover different countries, regions of Europe and sizes of city, there is no correlation between these factors and the issues addressed or the methods used. It is simply the case that sustainability covers many issues – environmental, sectoral and spatial. The nine cases cover greenhouse gas emissions, biodiversity, noise, ozone, local air quality (environment), waste and recycling, heat island effects, flooding; transport activity and patterns, energy use, food supply (sectors); compactness, provision of green spaces, settlement patterns (spatial). Furthermore, this wide range of different aspects are combined in different ways depending on the issues addressed by the assessment. Therefore, the possible combination of issues addressed even in this small sample of cases is very large and this leads to differences in methodology.

However, there are some more general differences. As noted above, some of the cases consider economic variables and some do not. There are different approaches to transport analysis: the Paris and London cases have transport – land use interaction models, the Helsinki-Lahti case uses regional settlement structures and transport networks to analyse transport provision and activity and resulting emissions and the Debrecen case uses a transport network model. Spatial settlement data is used for input into indicators for the provision of green spaces in the Vitoria and Kaunas cases, indicators for energy efficiency in the Linz case, and for the association of environmental impacts such as local air quality, flood risk, ozone etc. in most of the cases.

4.4.1 Data collection issue

An important consideration for interaction with policy stakeholders is a strategic perception that a request for more information is often seen as a response to delay taking action. Therefore, what is important is not to highlight the need for collecting a large quantity of data and how difficult this will be. Instead, an IA process should start by assessing the available data and performing preliminary analyses with the available, possibly very limited, data and then when a process of

interaction between modellers and stakeholders is underway, to find ways to improve the data available.

A further issue with city level assessments is that of data availability, which could prevent direct methodological transfer from one city to another. Integrated assessments are more complex than single disciplinary assessments, because they involve multiple assessments and multiple data sources. There is less data available at smaller scales in general and because the data collection may be for city purposes there are different data available for different cities. The cases show that data often has to be collected for the assessment, instead of relying on statistics that are already collected. The structure of local governance may also influence the collection of data – e.g. in the UK, some data is available at the ward level of political subdivision, while other cities may only collect data for the whole city.

However, data is becoming cheaper and cheaper to collect and computational power is also readily available. The cases summarised here show that even in smaller European cities, detailed data is often available, particularly for spatial analysis. The travel data available in Helsinki-Lahti is a good example of a highly detailed data collection exercise that is ongoing and enables very detailed transportation modelling as well as collection of energy consumption-data for the Linz case.

Spatial data based on GIS information is now widely available, whereas economic data such as Input-Output matrices are often only available at the national scale. Data availability may also influence the methodology used as the computer modelling approaches require fairly complete data sets for a reasonable calibration. The Paris and London cases are based on well-established data at the regional and local level, as are the Helsinki-Lahti, Debrecen and Luxembourg cases. The Vitoria and Novi Sad cases are examples of how particular data sets can be used for indicator analysis based on aggregated data, which may be easier to collect than detailed data. Detailed data appears to be available in a large number of cases on mobility behaviour through travel surveys and on land use structure through GIS. Aggregate sectoral data is also often available at the regional level, as in the Paris (sectoral economic activity), London (Input-Output matrices) and Luxembourg and Linz (energy demand and technology) cases. Only the London case study accounts for the uncertainties associated to the modelling results in the decision process. The London case shows that uncertainty considerations can benefit to arrive at better decisions. All other studies do not consider uncertainties associated to modelling results but rather address uncertainties due to an uncertain future climate and population developments.

Data are typically of various quality and occur at different scales. Data are often available but models need to be adapted as the required data are often not available at the required scale. In general, IAMs are a suitable approach also to adapt to data situations. If uncertainties were considered more, the influence of data quality could be demonstrated better. In order to better provide existing data integrated spatial data infrastructures (SDIs), such as the INSPIRE directive proposes can help gathering data and integrating distributed data sources to foster integrated assessment modelling and make data collection an easier task.

5 Links with decision makers and governance

5.1 Operational conclusions of case studies, and pertinence of the approach

The nature of integrated assessment, as shown in these nine cases, is that it is a class of analysis (and modelling) that is intended to support practical decision making, in this case at the city level. It should be noted that these analyses are all aimed at city level decision making, but the approaches to spatial analysis and environmental impacts can also be applied to district/local level decision making.

Sustainability assessment starts from the perception that the current society is unsustainable, whether through greenhouse gas emissions, local air quality, biodiversity or other environmental considerations. This means that the nature of the analysis is to look for changes that will ‘improve’ or increase the sustainability of the city society. However, this is a very difficult policy problem in the two critical areas of transport and energy, because city morphology, transport and energy demand and patterns of human behaviour are interconnected and therefore locked-in to current behavioural choices dependent on the housing and sectoral structure of the city (Köhler, 2006). The policy challenge is to overcome ‘business-as-usual’ development paths. Because of the behavioural lock-in, changes in city morphology and individuals’ decision making have to be addressed simultaneously. This requires assessment structures which incorporate the multiple dimensions, i.e. integrated assessment. The outcomes of these assessments, usually produced as scenarios, have to show the combination of measures addressing the several policy dimensions that are necessary to enable change.

All the cases show that the analyses are used to provide supporting evidence for decision making, sometimes involving trade-offs between different aspects of sustainability in the city context. As discussed above, this then requires the balancing of different aspects of the problem. The cases and their output show that the usual approach is not to provide output values and weights for a multi-criteria analysis, but rather to provide quantitative information as far as this is possible. The role of stakeholders and policy makers is then to make the necessary qualitative judgments, not only on the weights of the different variables in the output, but also on the aspects of the decision not included in the modelling. An integrated assessment study can also help decision making by stating clearly the aspects of the problem not included in the quantitative analysis.

5.2 Communication and acceptance of the results

A further issue that arises with respect to links to decision makers is the communication of the results. Overall, because urban level IA analyses are complex, it is necessary to have a simple, graphical representation of the vision of a plan, which can then be supported by more detailed results.

A further important point is that city authorities are often highly sensitive to comparisons with city which they perceive as competitors in the region and often have an international perspective. Many larger (EU) cities have the resources to consider practices in other cities and try and identify best practices, even at a global level. In the case of Helsinki, the main competitor cities are perceived to be Stockholm and Oslo, while the pathway of development is considered to be strongly influenced by developments in Tallinn and particularly St. Petersburg. Therefore, regional planning is often

influenced by international relationships, which must then be considered as one of the necessary scales of analysis.

5.2.1 A diversity of dimensions

Because an integrated assessment has several (or many) different dimensions and perspectives, the analyses often generate a complex set of results. A clear example of this are the Vitoria case, which in theory terms is not so complex, but generates 50 indicators of urban sustainability. A further example is the London case study, which combines several separate models in an integrated assessment system: a regional macro-econometric Input-Output model, a district (ward) accessibility based transport demand model, a flood risk model etc. These assessments therefore produce a large volume of complicated data, which cannot be just reported as one set of results.

One possibility is to communicate the assumptions and a sub-set of the results e.g. the flood risk maps for different scenarios in the London case. This is what is usually done. However, this obscures the linkages between the different sub-systems in the integrated assessment, which provide the real added value of this type of analysis.

For assessments such as the transport assessments in Helsinki-Lahti, Debrecen or Kaunas, the results are organized around a single two dimensional problem, spatial development and transport. Detailed data can be provided, but because it only has to address these two aspects, which are geographical problems and can therefore be effectively represented by two dimensional mappings, the results can be quite effectively communicated through figures and maps. This also applies to the Novi Sad case. The Luxembourg case considers energy and emissions, but also produces maps of e.g. atmospheric ozone over the region analysed, so this is an intermediate case. The Linz case took the prime energy demand of the building as a reference. The links between the multi-sectoral energy technology analysis and the regional maps of atmosphere effects are generally difficult to explain. The LEAQ model for Luxembourg however connects the primary emissions from economic sectors (transportation, industrial, residential and commercial) to daily air quality levels via a software link and optimization program (Zachary et al., 2011; Reis et al, 2013).

5.2.2 The results are difficult to explain

Most operational conclusions of the models involve complex results, which are difficult to communicate effectively to stakeholders. This is illustrated in Figure 2.8 for the Paris case, where two-dimensional representations of land use constraints and transport times and costs are used to determine properties of the housing market and housing stock. The results are presented in 3 dimensional images for a set of output variables, which are difficult to interpret without a dialogue of explanation. However, in the Paris, London Linz and Helsinki cases, the models were developed with policy stakeholders who did understand the model and accept the results, with a resulting input into the policy decisions – an improvement over the situation in the past.

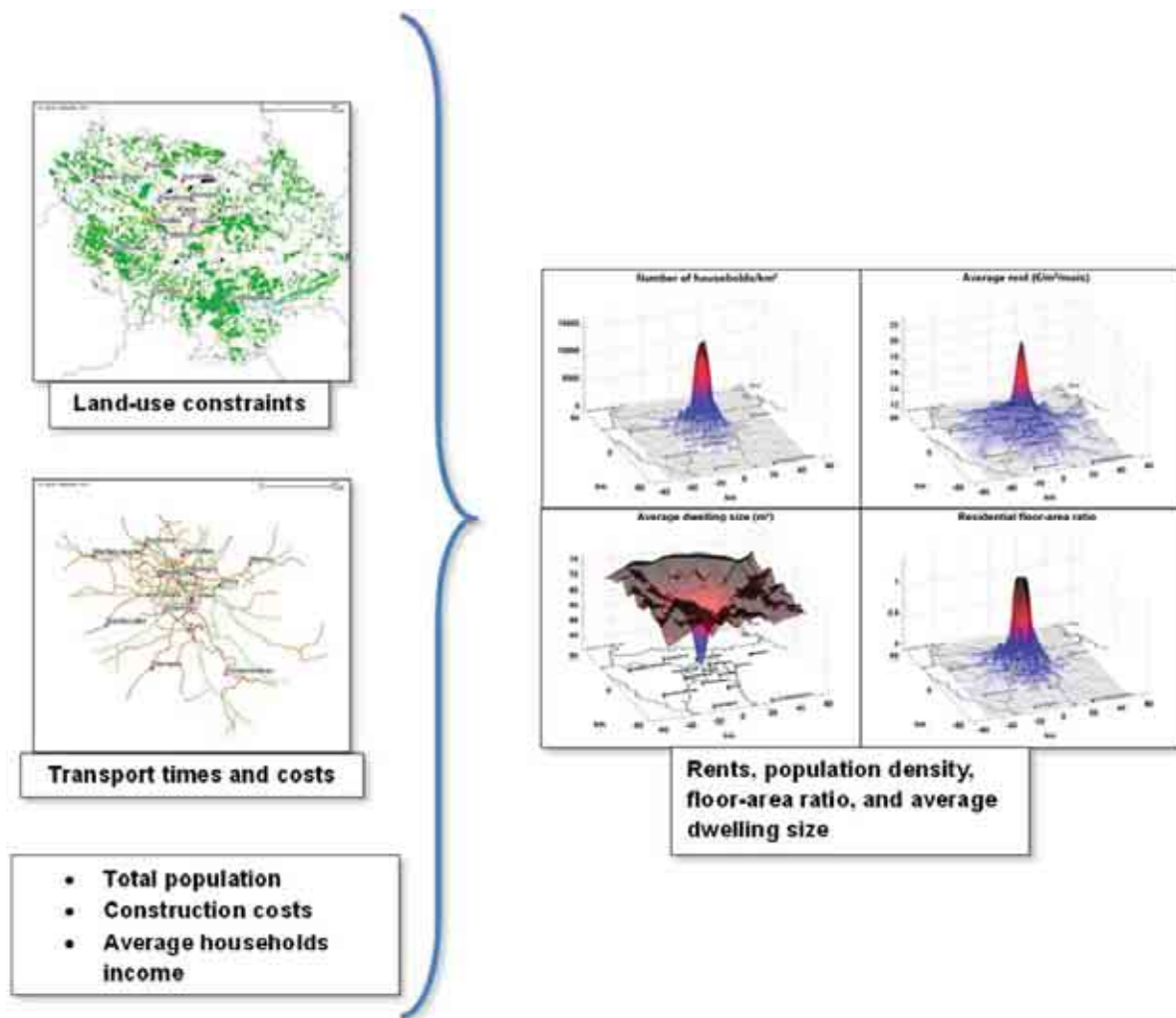


Figure 2.8 Description of NEDUM-2D model.

Another issue that arises is the communication of the uncertainty of the projections, especially the uncertainty surrounding social science related projections. In building integrated assessment model systems as in the Paris, London and Linz cases, it becomes very difficult to include feedbacks into the endogenous scenario generation where multiple models are involved. An important aspect of this is that it is in principle difficult to include social feedbacks in models – i.e. policy changes due to e.g. climate impacts or local air pollution.

These policy feedbacks themselves involve a complex set of social and political processes which cannot be realistically modelled, given the complexities of the social structures and the difficulty of quantifying them. The overall result is that integrated assessment modelling systems tend to have a single direction of causality.

In the London case, this chain consists of data (economic, social, transport) through transport activity models and economic activity models to generated patterns of transport and settlement activity which generated e.g. heat island effects and flood risk. Changes through changes in policy decisions have to be input as exogenous scenarios. This means that in principle, the integrated assessment has to be run iteratively, with different policy scenarios being tried in the assessment system to see how they contribute toward sustainability goals. However, this feature can be used to advantage in the decision making process, if the stakeholders are able to choose the scenarios and change them given the assessment outcomes.

As a conclusion, further research is required in our opinion on how to communicate these links or sensitivities effectively. Visualisation is vital for the communication of such complex sets of results (e.g. IEHIAS, 2005), with maps as shown in the case studies a minimum level of communication, which requires improvement. In some cases the information can be simplified by aggregation into summary indicators, where this is meaningful e.g. average temperature change over a city, total GHG emissions from a city, total employment in a city. The Kaunas study also provides an interesting example of how to summarise two complex spatial data into summary indicators showing an overall structure (the fractal indices in this case). However, it is often necessary to provide spatial data such as for transport flows in map form, usually through GIS database software.

5.3 Consequences for governance analysis

Multiple policy dimensions may require multiple governance actors to coordinate policy action. The connections between the local and city scales mean that there has to be coordination of action between the city-wide governance structures and local governance structures as well as different areas of policy making e.g. planning and energy. The cases mostly have links into the planning processes at the city level, but even though only one level of governance is then addressed, there is still the problem of how to collaborate successfully with different departments within a city governance structure. The cases suggest that usually, there is a strong link to a particular department e.g. the transport planning in the Helsinki-Lahti and Debrecen cases or the economics department in the London case and the city planning department in Linz. The connections to other departments tend to be coordinated through this 'lead' department.

One example of a project connecting models and governance is the LUXEN (LUXEN, 2013) project where the ETEM model was coupled to a general equilibrium model to explore several potential scenarios based on population, demographics, energy costs, and emission regulations.

The cases raise several general issues of governance. One question is how to bring in multiple viewpoints in a democratic way? An example is provided by transport planning in Helsinki, where proposals to replace motorways by urban road and other modes, in order to release land for development, is opposed by motorists who perceive a loss in their mobility.

A further issue is how to match many local initiatives at e.g. city district level with the overall planning priorities and structures. This requires some top-down management of the development process. If the city is part of a metropolitan region, it will be necessary for the analysis and decision structures to cover the whole relevant region. If the decision making and analysis only cover the city within the region, major flows in commuter transport, goods and environmental impacts close to, but outside the city administrative boundaries may be missed, defeating the point of an integrated modelling and planning process. A related issue is that of the balance of political power in decision making and implementation between the city and other authorities in the region. The issues between centres of authority can be illustrated by integrated assessment, but require an analysis framework that includes both the overall regional scale and the individual authorities and their interconnections.

In general, integrated assessment presents a difficult challenge for local and regional authorities/governance levels. Because of the hierarchical organizational structure of these organisations, analyses that connect different issues/disciplines cross organizational boundaries and are therefore not compatible with the decision making structure. In order to address this, it is

necessary to have a single individual with responsibility for the stakeholder use and input into an integrated analysis, with contacts in the different departments. A further aspect is that an effective plan for sustainability in a city needs to be interpreted in a consistent way by all the different departments involved in the planning and development process. This requires the development of common planning methods and criteria that are used by all departments and that are consistent with any (multi-criteria) modelling analysis that is undertaken.

6 Conclusions

The cases show that integrated sustainability assessment at the city/urban area level are being used to assess a wide range of sustainability issues. Given the choice of sustainability as a perspective, the other common feature that the assessments have is that they usually have spatially explicit analysis and data. They use a range of methods from integrated models to non-model indicator calculation from data.

Integrated assessments are more complex than single disciplinary assessments, because they involve multiple assessments and multiple data sources. However, data is becoming cheaper and cheaper to collect and computational power is also readily available. The most serious difficulty is giving the modelling an effective role in the decision making process, because the assessment may take some time to perform and the results are complicated and therefore difficult to communicate.

Data availability is in our opinion not a fundamental problem. The point of integrated assessment is to show the links between different parts of the social and environmental system, in this case in a city. While detailed data enables a more accurate and possibly convincing analysis, simple data can enable a simple integrated assessment. If e.g. a small, poor city does not have much resources, it is still possible to compare maps of different aspects and their spatial variation over the city e.g. population density and air quality. A simple integrated assessment can still help to assess policies and links between perspectives and whether qualitative conclusions of complex assessments are generalizable or not.

The cases summarised here show, however, that even in smaller European cities, detailed data is often available, particularly for spatial analysis. The travel data available in Helsinki-Lahti is a good example of a highly detailed data collection exercise that is ongoing and enables very detailed transportation modelling. There is also the collection of energy consumption-data for the Linz case.

What is missing in these case studies is a detailed assessment of how they have linked into decision making processes. It is also possible to ask the question, what is the way forward given the evidence of these case studies. In our opinion, the most important aspect is the integration of integrated assessment methods into city level planning processes, as shown in the Trondheim case and also used in the transition management literature (Grin et al., 2011). Another possibility is to use open source code to develop web based tools for development of modular integrated assessment tools. Two examples of this are the RFSC – Reference Framework for Sustainable Cities (RFSC, 2013) and the integrated Geospatial Urban Energy decision Support System (iGUESS) developed in the MUSIC project (de Sousa et al., 2012).

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Photographer: Richard Dawson



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Adaptation and mitigation – how addressing climate issues stimulates integrated thinking

Section III

Adaptation and mitigation – how addressing climate issues stimulates integrated thinking

Oliver Heidrich¹, Marta Olazabal², Johannes Flacke³

¹*School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne; NE1 7RU, U.K.;
oliver.heidrich@ncl.ac.uk;*

²*Basque Centre for Climate Change (BC3), Alameda de Urquijo 4, Bilbao 48008, Spain;
marta.olazabal@gmail.com;*

³*University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), PO Box 217, 7500 AE
Enschede, The Netherlands; j.flacke@utwente.nl*

Global climatic change can pose serious threats to cities and their inhabitants. At the same time they are responsible for a substantial share of the CO₂ emissions that can exacerbate climate change. Such a vicious circle puts cities among the most vulnerable and important places on earth. Adaptation to climate change, i.e. addressing the consequences of climate change, and climate change mitigation, i.e. reducing the cause of climate change, are the two principle strategies cities can follow to reduce these causes and threats. As will be seen in this section, if implemented together they can also provide opportunities and stimulate integrated thinking as they cross various sectors and administrative boundaries within and outside the jurisdictions and control of local authorities. Each sub-section and textbox and selected findings are now summarised below.

Reckien et al. compiled a database of published climate change mitigation and adaptation plans of 200 cities from 11 European countries. They conducted statistical analysis which provided the basis for an assessment of the breadth and ambitions of the cities. They found that although some two-third of cities had a mitigation plan, only about one third had an adaptation plan. The analysis yields a strong North-South divide with respect to local climate change planning. Crucially international climate networks e.g. Covenant of Mayors, seem conducive to successful mitigation planning within the cities surveyed. The authors plead that such networks could also be of great benefit for cities' success in adapting to climate change.

This is followed on by a more detailed analysis by Salvia et al. investigating urban planning and strategy policy documents related to climate change mitigation actions across 32 Italian cities. They clustered cities according to homogenous descriptors of climate policy strategies. In contrast to Reckien et al., they have not found clear patterns of cities' responses across Italian Northern and Southern regions or within large and small cities. The cities and their plans show different levels of ambition to reduce emissions (i.e. mitigation targets), reflecting the different political commitment of Italian local authorities. It appeared that local action is hindered by the lack of guidelines as well as by the scarce coordination of the climate action undertaken by the different tiers of government.

The importance of such different tiers of governance is demonstrated by a comparative study of Spanish and Italian cities conducted by De Gregorio Hurtado et al.. The authors explored the causes and consequences of multi-level climate governance on urban climate action by the different tiers of government (national, regional and local) in 32 Italian and 26 Spanish cities. The research identified the importance of constructing collaborative multi-level climate frameworks at the national scale, that fully integrate the local level, so that, acknowledging their responsibility they have in this policy field, cities develop consistent climate action with regional and national scales. The team argues that the greater integration of the climate policy action across the different tiers of government should be extended to other national contexts of the EU based on federal and other decentralized institutional structures.

Yet how can one rate, benchmark and evaluate the efforts by Local Authorities? Heidrich et al. (this volume) tailored the 'Plan, Do, Check and Act' principle, and present a methodology for an objective, standardised and quantitative Urban Climate Change Preparedness Score for UK cities. They investigated the content of mitigation and adaptation strategies, quantitative and qualitative targets, timelines for action and progress of their implementation across UK cities. The Authors present the Urban Climate Change Preparedness Score which allows a quantitative comparison of urban climate change plans and actions. This method can be transferred to other countries and makes national and international comparisons of climate change efforts and integrated assessment possible.

Adding to the relevant messages of the sub-sections described above, three textboxes highlight specific ranking and integrated models; starting with Kopytov et al. who compared five environmental assessment models using Riga (Latvia) as case study. They used differential equations theory to provide a stable analytical and numerical method and more precise data on the pollution, abatement costs and efficiency, which enables decision makers to determine the scale of the problems and select the appropriate solutions looking holistically at the problem.

Nanaki et al. assessed the CO₂ emissions from public bus transportation systems across nine European cities in 2010. The authors modelled the potential benefits of changing the bus fleets by assuming different penetration levels of five alternative biodiesel blends compared with the traditional diesel. They found that the cities of Madrid, Barcelona, Riga and Athens, which have the highest concentrations of diesel CO₂ emissions, could benefit the most.

Highlighting the idea of the benefits of rating and benchmarking the performance of climate change action at city level, Flacke and Reckien propose a Climate Engagement Index (CEI). This index provides an aggregated score combining a city's activities in the fields of local adaptation and mitigation planning with institutional indicators and the citizens' perception of municipal performance.

Section III-1

Urban climate change response and the impact of climate networks in Europe

Diana Reckien¹, Johannes Flacke², Sonia De Gregorio Hurtado³, Monica Salvia⁴,
Oliver Heidrich⁵, Richard J. Dawson⁵, Marta Olazabal⁶, Aoife Foley⁷, Hans Orru⁸,
Davide Geneletti⁹, Filomena Pietrapertosa⁴

¹ Columbia University, Center for Research on Environmental Decisions, 406 Schermerhorn Hall – MC5501, 1190 Amsterdam Ave, New York, NY 10027, USA; dianareckien@gmail.com.

² University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), PO Box 217, 7500 AE Enschede, The Netherlands; flacke@itc.nl.

³ Universidad Politécnica de Madrid, Escuela Técnica Superior de Arquitectura. Avenida Juan de Herrera 4, 28005 Madrid, Spain; sonia.degregorio@upm.es.

⁴ Institute of Methodologies for Environmental Analysis - National Research Council of Italy (CNR-IMAA), C.da S.Loja, 85050 Tito Scalo (PZ), Italy; salvia@imaa.cnr.it; fpietra@imaa.cnr.it.

⁵ Newcastle University, School of Civil Engineering and Geosciences, Newcastle upon Tyne, NE1 7RU, UK; oliver.heidrich@newcastle.ac.uk; richard.dawson@newcastle.ac.uk.

⁶ Basque Centre for Climate Change (BC3), Alameda de Urquijo 4, 48008 Bilbao, Spain; marta.olazabal@gmail.com.

⁷ University College Cork, School of Engineering, College Road, Cork, Ireland; aoife.foley@ucc.ie.

⁸ University of Tartu, Department of Public Health, Ravila 19, 50411, Tartu, Estonia; hans.orrut@ut.ee.

⁹ University of Trento, Department of Civil, Environmental and Mechanical Engineering, Via Mesiano 77, 38123 Trento, Italy; davide.geneletti@ing.unitn.it.

Highlights

- After accessing and contacting local authorities we reviewed approved and/or published urban climate change mitigation and adaptation plans from 200 cities in 11 European countries, and statistically analysed the plans' regional distribution across countries and cities' commitment in international climate networks.
- Climate change response of European cities, i.e. the number of officially approved urban adaptation and mitigation plans or those in process of development, is uneven across the 200 cities and 11 countries investigated.
- Based on a representative sample of cities in terms of city size and regional, as well as population covered in each country, the analysis yields a strong North-South divide.
- About two-third of cities investigated have a mitigation plan; only about one third has an adaptation plan.
- International climate networks seem conducive; the Covenant of Mayors Initiative of the European Commission is the most successful, particularly with respect to mitigation.
- There are no climate networks on the international level, such as the Covenant of Mayors, dedicated to adaptation of climate change, which is highly needed.

1 Introduction

As more and more people live in urban areas, it is those geographic areas, i.e. cities¹ that are made responsible for a large share of global greenhouse gases emissions (Duren and Miller, 2012; Satterthwaite, 2008). This in turn, plus their high density of people, assets, and infrastructure (Hunt and Watkiss, 2011; de Sherbinin et al., 2007; Dawson, 2007; Butler and Spencer, 2010) makes them particularly vulnerable to climate change impacts and resource shortage. Thus, cities may prove pivotal for both mitigation of and adaptation to global climate change (Rosenzweig et al., 2010; Rosenzweig et al., 2011; Betsill and Bulkeley, 2007). But, how do cities actually perform? Section III-1 provides an overview of the climate change response of 200 cities in 11 European countries, i.e. their efforts in developing urban climate change adaptation and mitigation plans and policies.

Existing analyses of urban climate change response typically focus on large and prominent cities, such as London, New York or Mexico City, or groups of the world's megacities, e.g. the C40² (Castán Broto and Bulkeley, 2012; Romero-Lankao, 2012; Carbon Disclosure Project, 2012; Johnson, 2013). Furthermore, many studies rely exclusively on self-reported measures such as questionnaires and interviewing of city representatives (Carbon Disclosure Project, 2012; Carmin et al., 2012), which might incorporate bias. Evidently, a less subjective assessment and more representative selection of urban areas are needed to more accurately characterise the climate change response of cities. Investigations note the importance of international networks in increasing climate engagement of cities, and a lot has been published about the Cities for Climate Protection Campaign in the USA (Betsill and Bulkeley, 2004; Brody et al., 2008; Lindseth, 2004; Slocum, 2004), but little is known about the influence of other international, more European centered networks. We explore the state of urban climate change response in Europe by way of an objective empirical analysis of 200 large- as well as medium-sized European cities (Figure 3.1.1). We provide an overview of the breadth and kind of climate change response (adaptation or mitigation plans), the availability and height of urban greenhouse gas reduction targets, and the contribution of international networks to cities' achievements.

2 Methodology

We explore the state of urban climate change response in Europe by way of an objective empirical analysis of 200 large- as well as medium-sized European cities (Figure 3.1.1). To do so, we compiled a database that comprises the existence, breadth, and ambitions of local adaptation and mitigation plans and strategies, and a number of socio-economic characteristics for each city. The statistics are mainly taken from Eurostat (2012b), unless otherwise stated. All urban areas are listed in the Urban Audit (UA) database, selected from 11 of the EU-27 member countries.

The UA cities were selected by the European Commission, Eurostat and the national statistical offices based on the following criteria (Eurostat, 2010): (i) approximately 20% of the population is covered in every country; (ii) national capitals and, where possible, regional capitals are included; (iii) large (more than 250,000 people) and medium-sized urban areas (minimum 50,000 and maximum 250,000 population) are to be included; and (iv) urban areas should be geographically dispersed within countries. The UA cities are therefore a balanced and regionally representative sample of cities from European countries and so is our sample of 200 cities. We analyse all the UA

¹ The terms 'city' and 'urban area' are used interchangeably, though definition might vary across countries. We use data from the Urban Audit, which also refers to "cities" Eurostat (2012a).

² C40 is a network of the world's megacities taking action to reduce greenhouse gas emissions (C40cities 2013)

cities of the 11 European countries where authors have worked and are familiar with the language and respective urban and climate policies. The cities are representative of 16.8% of the EU-27 inhabitants and the respective countries cover 72.1% of the EU-27 population.

We gathered urban climate change responses in the form of strategic policy and planning documents, i.e. approved (by the relevant municipal authority) and/or published urban climate change adaptation and climate change mitigation plans. Adaptation plans incorporate actions that lead to the abatement or reduction of vulnerability to climate change; mitigation plans encompass actions that entail a reduction of greenhouse gas emissions. A document was considered relevant when it targets the entire urban area or city region and when climate change was explicitly stated as a motivation for the plan's development. Adoption of the plan was not a necessary condition if a draft document or sufficient information about the plan and its content was available. The document had to be published as a single strategy, a collection of separate climate change actions was not considered. Sectoral plans, with the exception of some 'energy plans', that were motivated by climate change were generally excluded (e.g. 'transport strategies' were not considered). First, we conducted an Internet search. If no documents were available online, city administration officers were contacted directly to confirm that no climate change action plan existed or to provide the document. Thereby, we analysed the plans without relying on self-assessment of city representatives.

Additionally, we gathered membership data from a number of international climate networks active in Europe, comprising the Covenant of Mayors (Commission of the European Communities, 2012), the Climate Alliance (2012), the C40 climate leadership group (2013) and ICLEI Local Governments for Sustainability (2012). We provide a geographical overview and comparison of the existence of climate mitigation and adaptation plans, the existence and height of local GHG emission targets and descriptive statistics of climate network membership.

3 Results

3.1 Geographical distribution of climate plans

The analysis looks at the regional distribution of urban climate change adaptation and mitigation plans (Table 3.1.1). Overall, 65.0% of cities (130 cities) in our sample have at least a mitigation plan while 35% have neither a mitigation nor an adaptation plan. There is large variability across countries: 93% of UK cities studied have a mitigation plan (Heidrich et al., 2013), whereas only 43% of French and 42% of Belgian cities do. Most (88%) of the mitigation plans quantify targets for carbon dioxide (CO₂) or GHG emission reduction, applying either to the urban area as a whole, the city administration or certain economic sectors. Less than a third (28%) of cities has an adaptation plan. Cardinaly, no city has an adaptation plan without a mitigation plan, i.e. all adaptation documents were published simultaneously or after an existing mitigation document. The highest proportions of cities with an adaptation plan are in the UK (80% of 30 cities), Finland (50% of 4) and Germany (33% of 40 cities). In 22% of all cities studied, the mitigation and adaptation actions are integrated into a joint strategy (predominantly in the UK, Finland, and France), which increases the likelihood of integration and consideration of possible trade-offs and feedbacks between adaptation and mitigation policies (Viguie and Hallegatte, 2012; Dawson, 2011; Barnett and O'Neill, 2010). Overall, 25% of cities have both an adaptation and a mitigation plan and set quantitative targets for GHG emission reductions. In the context of our analysis we consider these

cities to be 'climate leaders'. Despite the advanced stage of environmental policies in Europe these are not plenty (see Table 3.1.1).

Table 3.1.1: Distribution of climate change plans across the selected countries. Joint mitigation and adaptation plans are an indicator for the integration of adaptation and mitigation issues. It denotes the publication in one volume. Urban climate leadership describes cities with an adaptation and a mitigation plan that also set quantitative targets (Reckien et al., 2014).

Urban Audit Cities in country:	with:						being:				
	Cities	No plan		Mitigation plan		Adaptation plan		Joint mitigation & adaptation plan		Climate leaders	
	<i>N</i>	<i>N</i>	[%]	<i>N</i>	[%]	<i>N</i>	[%]	<i>N</i>	[%]	<i>N</i>	[%]
Austria	5	2	40.0	3	60.0	0	0.0	0	0.0	0	0.0
Belgium	7	4	57.1	3	42.3	0	0.0	0	0.0	0	0.0
Estonia	2	1	50.0	1	50.0	0	0.0	0	0.0	0	0.0
Finland	4	1	25.0	3	75.0	2	50.0	2	50.0	1	25.0
France	35	20	57.1	15	42.9	8	22.9	6	17.1	8	22.9
Germany	40	8	20.0	32	80.0	13	32.5	6	15.0	12	30.0
Ireland	4	2	50.0	2	50.0	0	0.0	0	0.0	0	0.0
Italy	32	14	43.8	18	56.3	1	3.1	0	0.0	1	3.1
Netherlands	15	3	20.0	12	80.0	3	20.0	2	13.3	3	20.0
Spain	26	13	50.0	13	50.0	5	19.2	3	11.5	4	15.4
United Kingdom	30	2	6.7	28	93.3	24	80.0	24	80.0	20	66.7
TOTAL	200	70	35.0	130	65.0	56	28.0	43	21.5	49	24.5

3.2 Engagement in international climate networks

We analysed the membership of cities in international climate networks. Table 3.1.2 shows that the European Covenant of Mayors (CoM; Commission of the European Communities, 2012) is most successful in engaging cities. The CoM is the mainstream European movement involving local and regional authorities voluntarily committing to energy efficiency and use of renewable energy sources on their territories. Covenant signatories commit to at least meet the European Union 20% CO₂ reduction objective by 2020. CoM was launched by the European Commission after the adoption, in 2008, of the EU Climate and Energy Package to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies. The results show that CoM is very successful in engaging cities across a large number of countries. Almost 50% of cities are members of CoM.

The Climate Alliance (CA, 2012) is the second largest network engaging UA cities in the investigated countries. It has about half as many investigated cities as members as CoM has, but with a nationally, clustered membership along the Germanic countries. For instance, at least 80% of the German and Austrian cities in the selection are members of CA, whereas the Estonian, Finnish, Irish, Spanish and UK cities in the selection have no members.

The International Council for Local Environmental Initiatives (ICLEI, 2012) is the third most successful international climate network and, like the CoM, is active across a large number of countries in Europe. It promotes local action for global sustainability and supports cities to become sustainable, resilient, resource-efficient, biodiverse, and low-carbon. Also, it supports cities to build a smart infrastructure and to develop an inclusive, green urban economy with the ultimate aim to achieve healthy and happy communities. It is the only network in our selection that incorporates sustainability, impact and adaptation issues; therefore, it places its efforts on mitigation and adaptation alike.

The C40 Climate Leadership Group (C40cities, 2013) is restricted to large cities. It is an international network of the world's megacities committed to addressing climate change through action to reduce greenhouse gas emissions. As we included large and medium-sized cities not many European cities in our sample are members of the network.

Table 3.1.2 Urban Audit cities' membership in international climate networks. The table shows how many of the cities in each country are member in international climate networks, The data are taken from the networks websites (ICLEI, 2012, Climate Alliance, 2012, C40cities, 2012, Commission of the European Communities, 2012)(Reckien et al., 2014; amended).

Urban Audit Cities									
in country:	that are:								
	Cities	ICLEI Members		Climate Alliance		C40		Covenant of Mayors	
	<i>N</i>	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Austria	5	2	40.0	4	80.0	0	0.0	0	0.0
Belgium	7	1	14.3	1	14.3	0	0.0	4	57.1
Estonia	2	1	50.0	0	0.0	0	0.0	1	50.0
Finland	4	4	100.0	0	0.0	0	0.0	4	100.0
France	35	7	20.0	1	2.9	1	2.9	18	51.4
Germany	40	9	22.5	35	87.5	1	2.5	17	42.5
Ireland	4	1	25.0	0	0.0	0	0.0	2	50.0
Italy	32	3	9.4	5	15.6	2	6.3	17	53.1
Netherlands	15	3	20.0	1	6.7	2	13.3	7	46.7
Spain	26	5	19.2	0	0.0	2	7.7	17	65.4
United Kingdom	30	6	20.0	0	0.0	1	3.3	13	43.3
TOTAL	200	42	21.0	47	23.5	9	4.5	98	49.0

3.3 Comparison of urban engagement and climate networks

Figure 3.1.1 shows the geographic distribution of mitigation and adaptation plans within countries. Capital cities and C40 cities are also displayed to achieve an overview of the performance of large cities. Many large and capital cities have climate plans, but not all, and many only have mitigation plans. Dublin, Vienna, Rome, Helsinki and Tallinn do not have an adaptation plan.

Additionally, we display the percentage of cities in each country that are members of the CoM, the most active network in Europe. The UK, Germany, the Netherlands and Finland are the countries with the highest relative number of urban mitigation plans (Table 3.1.2). However, those are not the countries with the highest relative number in climate network membership, as judged with respect to CoM. The UK, German, and Dutch cities are not very active in this network (though Finish cities are). Cities in other countries of Europe, such as Spain, Belgium, Italy, France, Ireland, and Estonia (in order of highest to lowest percentage of network membership; Table 3.1.2 last row) are the most active in the CoM—and characterised by lower percentage of urban adaptation and mitigation plans than those cities in the large, economically strong and prominent countries of Europe. We therefore conclude that the CoM is particularly popular in countries where few urban climate plans exist, i.e. urban areas not yet engage in climate actions.

4 Discussion

The European Union is an important contributor to global warming releasing approximately 11% of global carbon emissions (Commission of the European Communities, 2013) and has established some of the most ambitious supra-national targets and policies. Therefore, investigating the response of European cities to climate change is a valuable contribution to the international trends

of adaptation and mitigation efforts, although we acknowledge the limitations of a European study for global policy implications. Our indicators of climate change response and climate leadership allow for larger objectivity than, e.g., comparisons relying on self-assessment, but they are also rigid and consequently do not capture the complexity of the policy processes involved (Baker et al., 2012; Romero-Lankao, 2012). Furthermore, climate plans may not include activities within urban areas that are relevant to adaptation and mitigation but not labelled as such (Castán Broto and Bulkeley, 2012). Yet, the adoption of climate change plans indicates awareness of the cross-sectoral challenges that climate change poses in the urban environment. Furthermore, structural and/or small-scale but wide-ranging changes often start with a multi-sectoral planning process (Corfee-Morlot et al., 2011). Future studies ought to deeper investigate potential drivers and barriers of plan development as well as of the implementation of planned actions, which includes addressing monitoring and updating of plans (Heidrich et al., this volume) and documenting the success of plans in achieving climate change adaptation and mitigation (Millard-Ball, 2012).

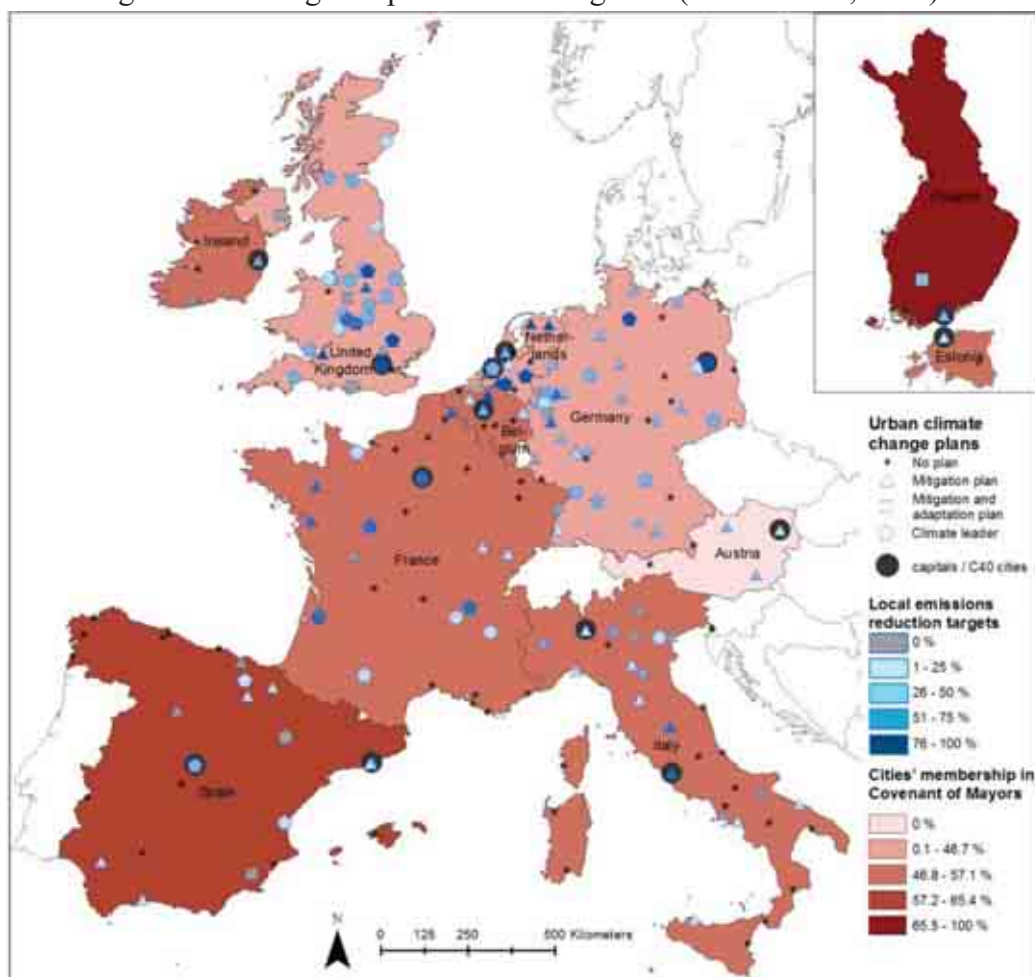


Figure 3.1.1 City location, climate change plans, and emission reduction targets for 195 of the 200 Urban Audit cities (5 are overseas). Countries are colour-coded according to the percentage of cities per country in the Covenant of Mayors. Cities that have an adaptation and a mitigation plan with quantitative targets are considered to be 'climate leaders' (pentagon marked) (adapted from Reckien et al., 2014).

5 Conclusions

In summary, our study reveals large variation in climate change response across this representative sample of urban areas in Europe—a variation that is particularly noticeable across the North-South direction. 35% of European cities studied have no dedicated mitigation plan and 72% have no

adaptation plan. No city has an adaptation plan without a mitigation plan. One quarter (24.5%) of the cities have both an adaptation and a mitigation plan and set quantitative GHG reduction targets, but those vary extensively in scope and ambition. Many cities engage in international climate networks and almost 50% of cities studied are engaged in the Covenant of Mayors Initiative of the European Commission. Particularly, cities in countries that have on average few urban adaptation and mitigation plans have many members in the network, which reveals its engagement success. As the Covenant of Mayors initiative is mainly focussed on mitigation issues, we conclude from this research—and in line with the EU Adaptation Strategy call (European Commission, 2013) and the subsequent report by ICLEI and the Committee of the Regions (ICLEI and CEPS, 2013)—that a similar network specially focused on climate adaptation planning and policy is urgently needed (particularly for the Southern European countries; as shown by De Gregorio (this volume) to overcome the lack of engagement in adaptation in many urban areas across the continent.

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Box III-1: Comparing emissions from 9 European cities and their bus fleets

Evanthia A. Nanaki¹, Christopher J. Koroneos, Dimitris Rovas, Jaume Roset, Tiziana Susca, Toke H. Christensen, Sonia De Gregorio Hurtado, Adam Rybka, Eugene Kopytov, Oliver Heidrich, Petra Amparo López-Jiménez

¹ University of Western Macedonia, Department of Mechanical Engineering, Bakola and Sialvera, 50100 Kozani, Greece, E-mail: evananaki@gmail.com

Urban mobility accounts for 40% of all CO₂ emissions of road transport and up to 70% of other pollutants from transport [EEA, 2009]. This study provides an overview of CO₂ emissions from public transportation systems across nine European cities in 2010. The average length of their urban bus networks is 8,7696 km. Barcelona and Madrid have the biggest bus network reaching 28,705 km and 25,916 km respectively. The average number and age of buses of the cities also differs greatly, which will have an impact on the emissions released. For example Madrid's bus fleet consists of 4,216 vehicles with an average age of 6.1 years. On the other end of the spectrum is Rzeszow's bus fleet which consists of 156 buses with an average age of 15 years. Also the vehicle type and category has an impact on the emissions. We calculated the emissions (E) released into air for each city by using the following equation:

$$E_{i,j} = \sum_k (N_{j,k} \times M_{j,k} \times EF_{i,j,k}) \quad (1)$$

where j are the vehicle categories of diesel buses, k is the technology of each category (i.e. EURO I, EURO II, etc), $N_{j,k}$ is the number of vehicles in the city's bus fleet of category j and technology k , $M_{j,k}$ represents the average annual distance driven per vehicle of category j and technology k , $EF_{i,j,k}$ represents the technology-specific emission factor of pollutant i for vehicle category j and technology k .

In terms of absolute CO₂ emissions Madrid and Newcastle appear to have the highest emissions released by diesel buses (1,028,422 and 543,109 tons of CO₂) followed by Barcelona and Athens (134,893 and 125,467 tons of CO₂). Not surprising, due to its small fleet size, Rzeszow is the city with the lowest emissions of CO₂ reaching 12,170 tons (Figure B3.1.1).

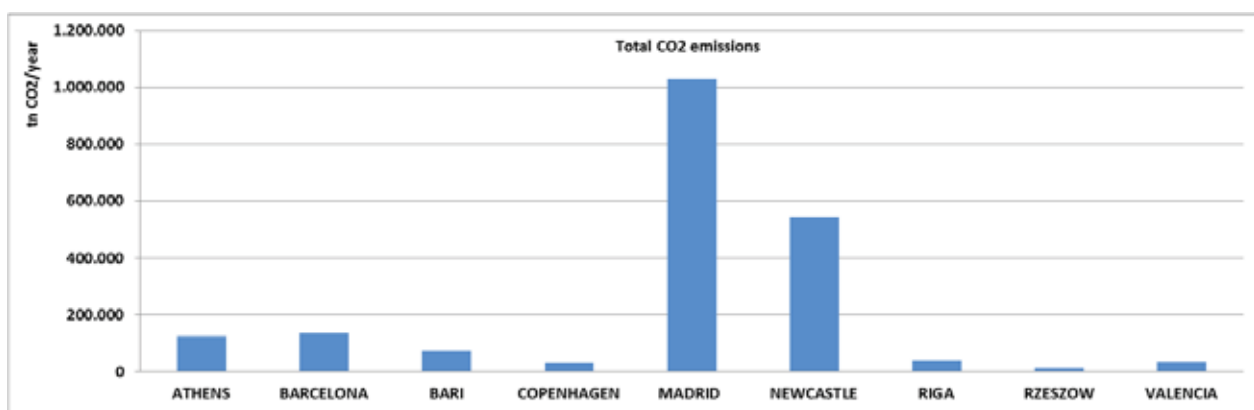


Figure B3.1.1 CO₂ emissions for each city's diesel bus fleet.

In order to determine potential benefits of changing fleets we estimated penetration levels of five alternative biodiesel blends with traditional diesel (B10 -10% biodiesel and 90% diesel, B30 - 30% biodiesel, B50- 50% biodiesel, B80- 80% biodiesel and B100- 100% biodiesel). B100 provides the best CO₂ emission reductions (78.5 % lower compared to equivalent diesel emissions). The cities of Madrid, Barcelona, Riga and Athens, which have the highest concentrations of diesel CO₂ emissions, could benefit the most (Figure B3.1.2).

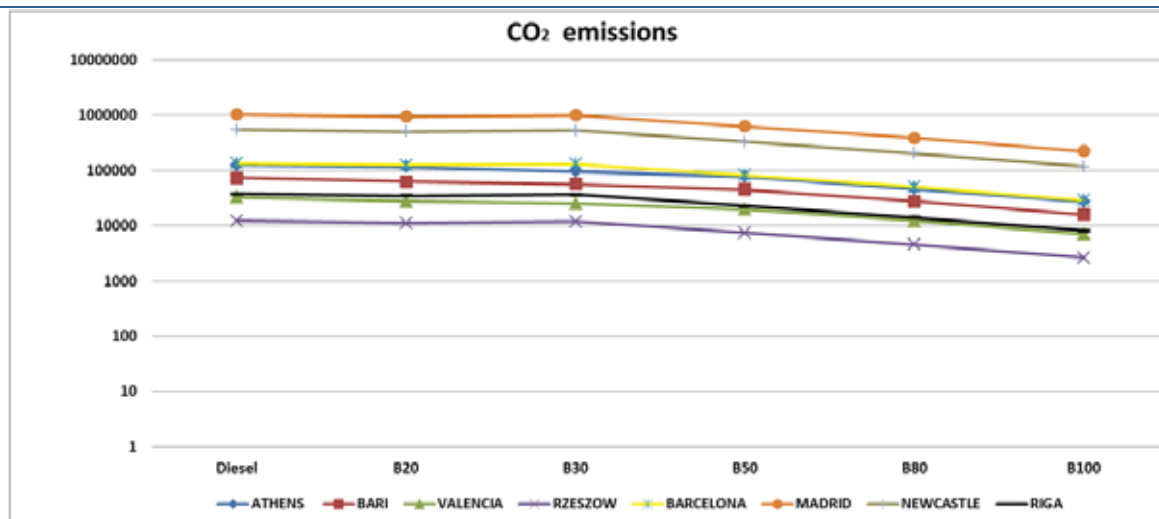


Figure B3.1.2 CO₂ emissions (tons) for the different biodiesel blends – logarithmic scale.

In addition, dense urban settlements can be seen reducing per capita carbon emissions through the concentration of services that result in shorter travel distances, the (generally) better provision of public transportation networks, and the constraints on the size of residential dwellings imposed by the scarcity and high cost of land (Figure B3.1.3).

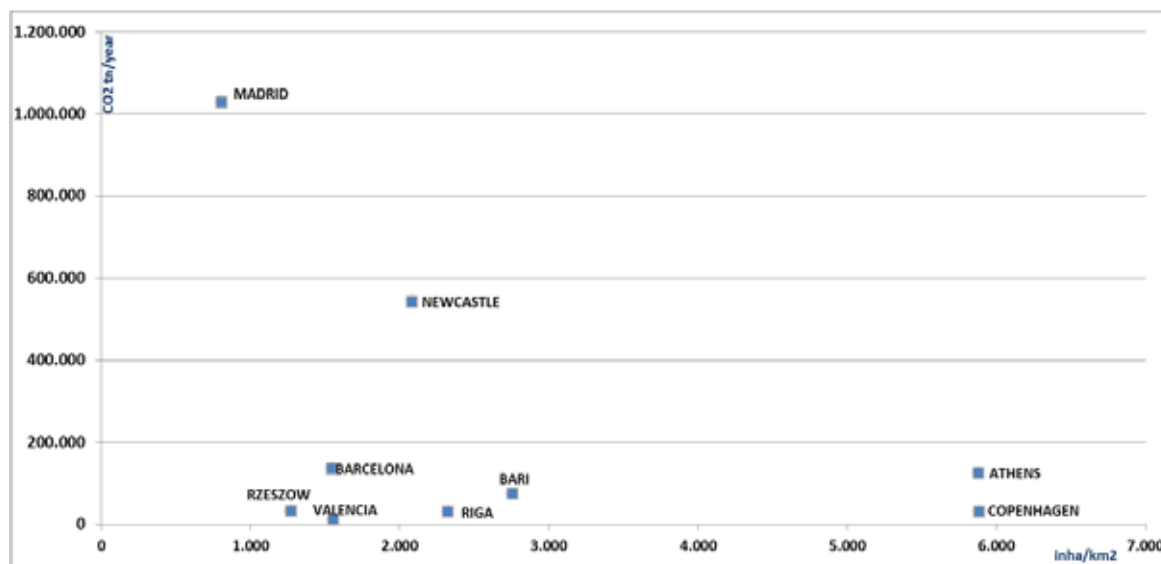


Figure B3.1.3 CO₂ emissions and population density.

We are certain that moving towards a low carbon transport system requires an integrated approach, taking into consideration environmental, economic and social parameters. Here we have shown that the levels of emissions resulting from the different systems in each city reflect the differences in the size of the cities, the length and utilisation of the bus network. However, changing the penetration levels of alternative fuels such as biodiesel blends will have a significant reduction of CO₂ emission at the city level.

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Section III-2

Evaluation of climate change plans and actions across cities

Oliver Heidrich¹, Diana Reckien², Claire L. Walsh¹, Richard J. Dawson¹

¹*School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne; NE1 7RU, U.K.;
Oliver.heidrich@ncl.ac.uk; richard.dawson@newcastle.ac.uk; claire.walsh@newcastle.ac.uk;*

²*Center for Research on Environmental Decisions, Columbia University; 406 Schermerhorn Hall – MC5501, 1190
Amsterdam Ave., New York, NY 10027, U.S.A.; dianareckien@columbia.edu*

Highlights

- This research compiled, reviewed and analysed climate change policies, strategies, plans and implementation programmes from 30 UK urban areas.
- We investigated the content of mitigation and adaptation strategies, quantitative and qualitative targets, timelines for action and progress of their implementation.
- We developed indicators for implementation status of the plan, monitoring and evaluation.
- An Urban Climate Change Preparedness Score for adaptation and mitigation climate change activities is proposed which allows a quantitative comparison of urban climate change actions.
- This methodology is demonstrated for UK cities but can be transferred to other countries and makes national and international comparisons possible.

1 Introduction

Cities and their administrations are pivotal to the implementation of global climate policy, both from mitigation and adaptation perspectives. They conduct risk assessments, set reduction targets and introduced policies, strategies, plans and programmes (henceforth collectively referred to as climate initiatives) to tackle climate change mitigation and adaptation issues in a coherent manner (ARUP, 2011; Carbon Disclosure Project, 2011; Hunt and Watkiss, 2011; Carmin et al., 2011).

A number of governments signed up to international mitigation commitments such as the Kyoto Protocol and the European Parliament commits its member states to reduce GHG emissions and energy consumption by at least 20% by 2020 from a 1990 baseline (European Parliament, 2009). In particular, the UK government has set the pace in terms of legislative framework with the Climate Change Act (2008) committing to a net reduction of the UK carbon account of 80% by the year 2050 (1990 baseline). Adaptation is typically behind mitigation strategies and a number of EU countries are publishing national adaptation strategies, although many lack a rigorous implementation and evaluation process (Biesbroek et al., 2010). Monitoring and evaluating adaptation and mitigation activities is important and needs to be supported by policies and strategies (Adaptation Sub-Committee, 2010; Rosenzweig and Solecki, 2010). This sub-section is based on Heidrich et al. (2013) giving insights into the state of urban climate change adaptation and mitigation planning from 30 UK cities (representing ~28% of UK population). It suggests a method of evaluating climate change documents and activities (Table 3.2.1 and Table 3.2.2). This is of

immediate use to national and international policy makers in order to monitor if their strategies are having the desired effect at the urban scales

2 Methodology

Urban areas were taken from the European Urban Audit database (Eurostat, 2010) and the method for selecting and analyzing documents is described in Reckien et al (this volume). Using published assessment frameworks and processes (Klein et al., 2001; ICLEI, 2008; UKCIP, 2009; Johnstone and Moczarski, 2011; Preston et al., 2011), we characterised the following four key stages of adaptation and mitigation (i) Assessment, (ii) Planning, (iii) Action, and (iv) Monitoring. Table 3.2.1 summarises the approach to assess those key stages. In summary, each stage is scored from 0 to 3 based on the following criteria for adaptation preparedness (Table 3.2.1):

- Assessment of current and future climate risks e.g. Local Climate Impacts Profile (UKCIP, 2009), climate change risk analysis and accounting of adaptation;
- Adaptation planning e.g. Adaptation strategy breadth and depth, standardised management systems such as e.g. BS EN ISO 14001 (2004)³ and NI 188⁴ (DEFRA, 2010);
- Adaptation action e.g. Quality of adaptation action plans and implemented projects;
- Adaptation monitoring and review e.g. Covenant of Mayor Signatory, level of senior management commitment and formalised procedures such as annual reviews.

Table 3.2.1 Summary of assessment method (see Heidrich et al 2013 for full description) to score preparedness of climate change adaptation activities (refer to Table 3.2.2 for status and scope classification).

Score	Assessment	Planning	Action	Monitoring
0	No evidence of assessment or acknowledgment risks found.	No evidence of climate change adaptation planning and/or scored 0 on NI 188.	No evidence of climate change adaptation action plans or project activities.	No evidence of monitoring and/or annual reviews
1	Acknowledges risk but not formalised (status A-B) and not published	Some evidence of planning (status A-B), but no formalised; scored 1 or below on NI 188.	Some case studies on website but not adaptation action plan (status A-B).	No monitoring but informal review (status A-B); informal commitments (e.g. website and/or declaration).
2	Some assessments (status C-D), no standardised method; coverage not across areas and sectors (scope AO).	Draft adaptation plan (status C-D) but not for whole area and sectors (scope AO); standard systems (e.g. 14001); scored 2 or below NI 188.	Action plan exist but not approved (status C-D); case studies; no link to the action plan, not across area and sectors (scope AO).	Management commitment but no procedure (status C-D); not across area and sectors (scope AO).
3	Publishes local climate impact profile; risk assessments; standardised method for whole area and sectors (scope AA); formalised (status E-F).	Publishes adaptation plan (status E-F) across area and sectors (scope AA); standard system (e.g. 14001); and/or scored 2 or above on the NI 188; formalised.	Provides authorised action plan (status E-F) across area and sectors (scope AA); follows up; report outputs; case studies; formalised.	Annual reviews (e.g. signed declarations (Status E-F); procedures in place; across area and sectors (scope AA); formalised.

³ A standard providing a framework organizations can follow to have a certifiable Environmental Management System.

⁴ National Indicator 188 was used to help local authorities assess and address the risks and opportunities presented by a changing climate, as well as provide a tool for measuring preparedness. NI 188 was withdrawn in 2011.

Table 3.2.2 Urban Areas and climate change (CC) documents analysed.

Urban Area	Population in 2010	Covenant of Mayor	Nottingham, Scotland, Welsh Declaration	Name of climate initiative analysed	Status ⁵	Authors	Date	Scope ⁶
Aberdeen	217,100	Yes	Yes	Climate Change (CC) action programme	F	Environment and CC Working Group	2002	AA
Belfast	268,700	No	N/a	Carbon management plan 2010-2015 Corporate plan 2008-2011	F	Carbon Group and Carbon Trust Councilors	2010 2008	AO AA
Birmingham	1,036,900	Yes	Yes	Sustainable development action plan 2009-11 CC action plan 2010+	F	Sustainable Development Steering Group Department for CC and Sustainability	2009 2010	AA AA
Bradford	512,600	No	Yes	CC strategy for Bradford district-DRAFT	C	Environment and CC Unit	2011	AA
Bristol	441,300	Yes	Yes	CC and energy security framework	C	Strategic Director – City Development	2010	AA
Cambridge	125,700	No	Yes	CC strategy and action plan 2008-2012 Environmental action plan	F	Environment and Planning Sustainable City Team	2008 2010	AA AO
Cardiff	341,100	Yes	No	Carbon lite action plan	F	Sustainable Development Unit	2010	AA
Coventry	315,700	No	Yes	Sustainable development action plan 2009-12 CC strategy for Coventry	F	Sustainable Development Unit CC, Housing & Sustainability	2009 2008	AA AA
Derry	107,300	No	N/a	Carbon management plan No published plan, strategy etc. available	F	Carbon Team and Carbon Trust n.a.	2009 n.a.	AO
Edinburgh	486,100	Yes	Yes	CC framework 2007-2015 Carbon management programme	unclear F	Carbon, Climate and Sustainability Team CCS Team and Carbon Trust	2007 2008	AO AO
Exeter	119,600	No	Yes	Sustainable Edinburgh 2020 CC strategy 2008-18	F	CCS Team Environmental Coordinator	2011 2008	AA AA
Glasgow	592,800	Yes	Yes	Carbon management programme CC strategy and action plan	F	Environ. Coordinator and Carbon Trust Development and Regeneration Services	2008 2010	AO AO
Gravesham	99,600	No	No	Sustainable Glasgow Report 2010 CC and environmental protection-baseline 2009	C unclear	Sustainable Glasgow not clear	2010 2009	AA NS
Kingston upon Hull	263,900	No	Yes	Environment and adaptation plan 2011-14 CC 2010-20 A low carbon framework	unclear F	not clear Environment and CC Advisory Group	2010 2010	AA AA
Leeds	798,800	No	Yes	CC strategy-vision for action CC action plan	F unclear	Environment Leeds and CC Partnership not clear	2010 2010	AA AA
Leicester	306,600	Yes	Yes	Carbon footprint statement CC adaptation action plan CC mitigation action plan	unclear E E	Environment Team Environment Team Environment Team	2011 2010 2010	AO AA AA
				CC mitigation plan for Leicester	E	Environment Team	2010	AA

⁵ Status is defined as: A- no official plan, strategy etc. exist; B- official decision to develop plans exist; C- preliminary work has commenced; D- draft plan published; E- final plan submitted for approval by Authority; F- Plan approved by Authority; NS- Not Stated; AO- Authority Only- covers only activities controlled by the Authority; AA- Across Authority- covers activities across the Authority i.e. activities controlled by the Authority, as well as activities by households, industry, businesses.

⁶ Scope is defined as: NS- Not Stated; AO- Authority Only- covers only activities controlled by the Authority; AA- Across Authority- covers activities across the Authority i.e. activities controlled by the Authority, as well as activities by households, industry, businesses.

Lincoln	89,700	No	Yes	CC strategy phase 1	F	Environmental Services	2005	AA
Liverpool	445,200	Yes	Yes	Carbon management programme	F	Environmental Services and Carbon Trust	2007	AO
London	7,825,200	Yes	Yes	CC strategic framework- prospectus of action	F	Regeneration Policy Business Unit	2009	AA
				The Mayor's CC adaptation strategy	F	Mayor of London and GLA	2011	AA
Manchester	498,800	Yes	Yes	The Mayor's CC mitigation and energy strategy	F	Mayor of London and GLA	2011	AA
				Manchester-a certain future-CC action plan	F	City Council (not specified)	2009	AA
Newcastle u. Tyne	292,200	Yes	Yes	Citywide CC strategy & action plan 2010-2020	F	Newcastle Partnership	2010	AA
				Newcastle CC declaration	F	Council (not specified)	2010	AA
				Newcastle CC action plan	F	Council (not specified)	2008	AO
Nottingham	306,700	Yes	Yes	Draft community CC strategy	C	CC Team	2011	AA
				CC adaptation action plan	F	CC Team	2011	AO
Portsmouth	207,100	No	Yes	CC strategy	F	Portsmouth Sustainability Action Group	2009	AA
				Carbon management programme	F	Council and Carbon Trust	2009	AO
Sheffield	555,500	No	Yes	Carbon reduction framework	C	Not specified	2009	AA
				Environmental strategy	F	Sheffield First	2007	AA
Stevenage	81,800	No	Yes	CC strategy	F	Borough Council	2009	AA
				CC strategy-action plan	F	Borough Council	2011	AO
Stoke-on-Trent	240,100	Yes	Yes	DRAFT sustainability and CC	C	City of Stoke	2010	NS
Wirral	308,800	No	Yes	CC strategy	F	Sustainability dep; Wirral CC Group	2007	AA
				CC strategy actions	F	Sustainability dep; Wirral CC Group	2007	AO
Wolverhampton	239,400	No	Yes	CC strategy and action plan 2009-12	F	Council and Wolverhampton Partnership	2009	AA
				Carbon management strategy and implementation	F	Council and Carbon Trust	2008	AO
Worcester	94,800	No	Yes	Worcester City Council CC strategy	F	Policy and Performance Team and CC WG	2009	AO
Wrexham	133,600	No	No	No published plan, strategy etc. available	A	n.a.	n.a.	
Total	17,352,700	13	25	52 documents analysed in detail				

Key stages of mitigation preparedness were similarly assessed (Heidrich et al 2013):

- Assessment of GHG and/or carbon emissions e.g. Status of carbon management programmes and other GHG accounting methods;
- Mitigation planning e.g. Mitigation strategies, plans and existing management systems to manage the process;
- Mitigation action e.g. Quality of mitigation action plans and implemented projects;
- Mitigation monitoring and review e.g. Covenant of Mayor Signatory, level of senior management commitment and formalised procedures such as annual reviews.

3 Results

3.1 General results

The 30 urban areas represent a population of around 17.3 million; with two in Wales (Wrexham and Cardiff), three in Scotland (Aberdeen, Edinburgh and Glasgow), two in Northern Ireland (Belfast and Derry) and 23 in England – including the UK capital (London) and the 8 largest economies outside London (Birmingham, Bristol, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield). By far the largest urban area is London, with a population of 7.6 million and the smallest is Stevenage with 81,000 inhabitants in 2010 (Office for National Statistics, 2011).

The vast majority (28) urban areas published climate initiatives outlining how they will tackle climate change adaptation and mitigation. Derry (Northern Ireland) and Wrexham (Wales) are at the start of this process and have not published an official decision or document tackling climate change. Urban areas are often part of larger Metropolitan, District and County Councils and some refer to a regional climate change strategy rather than providing one themselves e.g. Stoke on Trent (South Staffordshire Council, 2008) and Gravesham (Kent County Council, 2011).

The majority of urban areas (25) provide one document addressing both mitigation and adaptation; only Leicester, London and Nottingham provide separate strategies. Overlaps between initiatives are inevitable. In total, 307 documents were reviewed, of which 52 were analysed in detail (Table 3.2.2). The oldest, published in 2002, is the Climate Change Action Programme for Aberdeen. Mitigation and adaptation strategies for London were developed over many years, including a substantial public consultation, and were finally approved and published in October 2011.

3.2 Emissions reduction targets

The majority (48/52) of documents do refer to emissions reduction targets, although the timescales are unclear in some instances, e.g. for Lincoln City Council (2005). To be meaningful reduction targets require a baseline and a target year but only 8 documents use the 1990 baseline from the Kyoto protocol and UK Climate Change Act (2008). Figure 3.2.1 summarises the targets, where possible expressed in terms of CO₂ or carbon reduction that provide a baseline year and target year (green bar); target year but no baseline (shaded green bar) and where no targets are set (yellow bar). Edinburgh is probably the most ambitious with the aspiration to achieve a zero carbon neutral economy by 2050, but it does not provide a baseline (thus being illustrated using a shaded green bar).

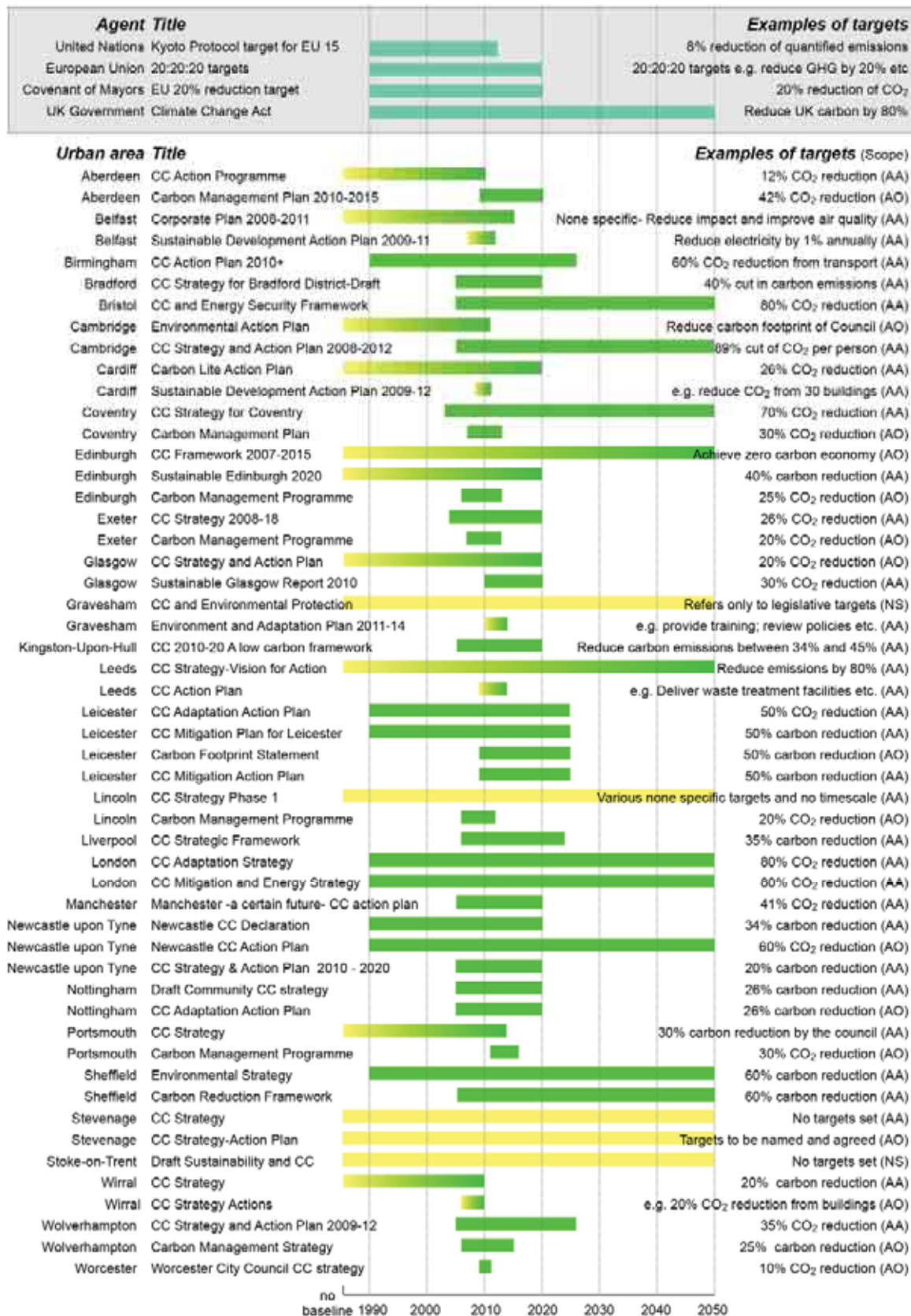


Figure 3.2.1 Examples of international and national targets; Emission reduction targets by the 30 cities and 52 documents analysed; Scopes- Across Authority (AA) includes household, industry and business, Authority Only (AO) under control of the Authority or Not stated (NS); Yellow- no target, yellow/green shaded- no baseline but target year, green- baseline and target year (Heidrich et al., 2013).

3.3 Urban Climate Change Preparedness Scores

The Preparedness Scores of the 30 urban areas in terms of assessing, planning, implementing and monitoring adaptation and mitigation are visualised in Figure 3.2.2. Overall, the highest scoring areas are Leicester and London, both providing separate plans for adaptation and mitigation (Leicester City Council, 2010a; Leicester City Council, 2010b; Mayor of London, 2011b; Mayor of London, 2011a), aligning these with the core strategy e.g. Leicester City Council (2010c) and providing regular reports and carbon footprints e.g. Leicester City Council (2011). Some areas provide other plans such as Cambridge City Council (2009) or London Climate Change Partnership (2009).

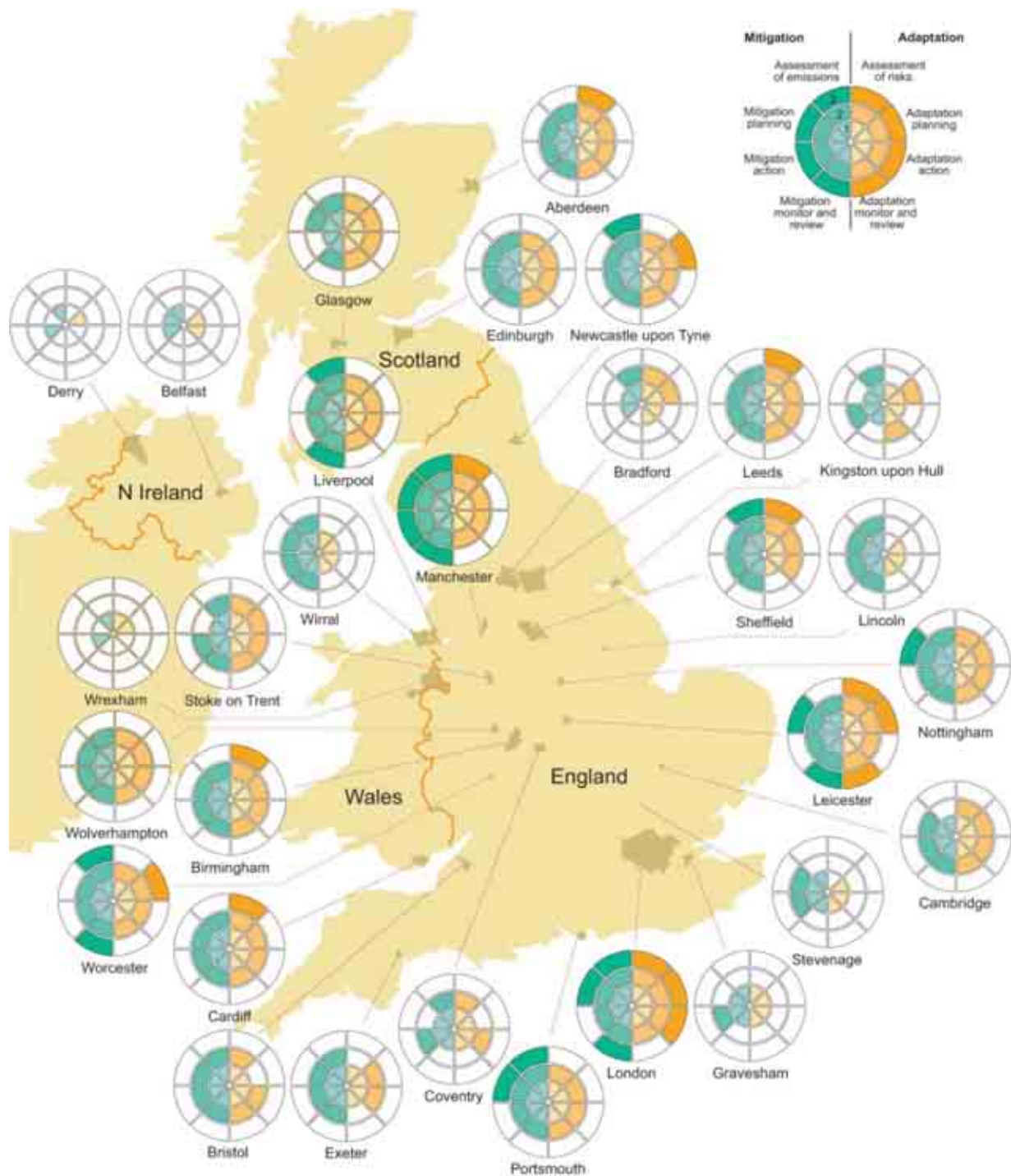


Figure 3.2.2 Climate Change Preparedness Scores of cities- 3 being most advanced (Heidrich et al., 2013).

Aberdeen, for example, scores a 3 for adaptation analysis, and although their adaptation plan (Aberdeen City Council, 2002) is a decade old, the Council completed a Local Climate Impact Profile in 2008. Across other categories, Aberdeen scores 2 as the council provides Carbon Programmes (Aberdeen City Council and Carbon Trust, 2010), have signed the Scotland's Climate Change Declaration and the Covenant of Mayors initiative, thus providing annual progress reviews. However, it is unclear if they have a standardised process or state of the art monitoring and reviewing. Derry, on the other hand, has only recently embarked upon tackling climate change and therefore scores between 0 and 1 in the different categories. Although Wrexham scores low as well the council considers mitigation to be a performance criteria (Wrexham County Borough Council, 2011), but planning, implementation and review processes are not established yet.

4 Discussion

The strengths of our Urban Climate Change Preparedness Score is that it is more informative than a single number as it captures both, quality and progress, recognising adaptation and mitigation processes, and that it is rapid to undertake and easy to visualise. It could therefore be undertaken at regular intervals to determine progress and provide a national overview to central government. The potential weakness of any such scoring system is that it may overly standardise strategies and their contents thereby reducing the potential for local innovation. Despite following assessment criteria a degree of subjectivity is inevitable.

From the 28 urban areas, 307 climate adaptation and mitigation documents were obtained, highlighting the plethora of climate initiatives. This analysis has shown discrepancies between plans within urban areas. For example in Cardiff, despite both emerging from the same department, the 'Carbon Lite Action Plan' (Cardiff Council, 2010) and the 'Sustainable Development Action Plan 2009-12' (Cardiff Council, 2009) cover activities controlled by the council, businesses and households (Scope 2) but the Carbon Lite Action Plan refers to district and decentralised energy generation, energy from waste, combined heat and power, tidal power and solar energy, whereas the Sustainable Development Action Plan does not refer to any of those mitigation measures but refers to biomass and wind energy, which in turn is not mentioned by the Carbon Lite Action Plan.

Our analysis shows (Table 3.2.2) that most documents are authored by sustainability/environment units, but they do not consider strategies across different sectors and are often not connected to sectoral strategies. For example, a transport strategy is often developed by the transport units and the different authorship and purpose of this strategy can lead to, at best, a missed opportunity in terms of maximising cross-sector benefits, or in some instances conflicting statements about mitigation targets and priorities. New business and delivery models are required that can more readily take advantage of potential co-benefits and ensure improved collaboration across relevant sectors and organisations.

There are many potential reasons as to why cities have different scores and our analysis shows that population or size of the city does not strongly correlate with the preparedness score for these 30 cities. London, Leicester and Manchester demonstrate a high level of adaptation and mitigation implementation and reviewing, as well as having an established process well embedded in their planning process. Bradford, Stevenage and Gravesham have strategies, but their monitoring process appears less well developed.

5 Conclusions

This analysis has provided insights into climate change policies, strategies, plans and programmes from 30 urban areas in the UK and has proposed a method to assess Urban Climate Change Preparedness. This scores the depth and progress of adaptation and mitigation policies at the city level and is sufficiently straightforward to enable rapid assessment across areas and even countries. It makes a national and international comparison of cities and their climate change adaptation and mitigation initiatives consistent, transparent and easy. Indeed, many systems considered (e.g. ISO 14001, Covenant of Mayors) are international. However, the information used here may need to be augmented to ensure country specific evidence is incorporated e.g. ‘Le Grenelle Environnement’ process for French Authorities (Ministère de l'Ecologie, 2012). Our method can be utilized by central government and voluntary organizations (e.g. ICLEI; Covenant of Mayors) to compare cities. Representatives from local government may be interested to benchmark their performance against other urban areas using the Climate Change Preparedness Scores.

This analysis has shown that UK urban areas of all sizes acknowledge climate change being a threat, although there is larger variation in the detail of analysis, targets and timeframes, as well as the degree of implementation. Urban areas not required to report their progress appear to be less advanced. We discovered not only national inconsistency amongst strategies but also inconsistencies of strategies that originated by the same authority or even the same department. Moreover, targets are seldom in line with international and national magnitudes or timescales. Given the importance of urban areas and spatial planning to manage climate impacts and reduce emissions, it is essential to embed adaptation and mitigation within the urban planning framework and the organisations responsible for delivering local infrastructure and services. This must be supported through local, national and international initiatives to stimulate and, where necessary, enforce appropriate action, monitoring and review.

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Section III-3

Mitigating climate change in Italy: a cluster analysis of urban responses

Monica Salvia¹; Filomena Pietrapertosa¹, Sonia De Gregorio Hurtado², Davide Geneletti³,
Valentina D'Alonzo³, Senatro Di Leo¹, Diana Reckien⁴

¹National Research Council of Italy - Institute of Methodologies for Environmental Analysis (CNR-IMAA), C.da S.Loja; 85050 Tito Scalo (PZ), Italy; monica.salvia@imaa.cnr.it; filomena.pietrapertosa@imaa.cnr.it; senatro.dileo@imaa.cnr.it;

²Faculty of Architecture (ETSAM). Universidad Politécnica de Madrid; C/ Alfonso XII, 3 y 5; 28014 Madrid, Spain; sdegregorio@mailpersonal.com

³University of Trento, Department of Civil, Environmental and Mechanical Engineering, Via Mesiano 77, Trento, Italy; davide.geneletti@ing.unitn.it; valentina.dalonzo@ing.unitn.it;

⁴Center for Research on Environmental Decisions, Columbia University; 406 Schermerhorn Hall – MC5501, 1190 Amsterdam Ave., New York, NY 10027, U.S.A.; dianareckien@columbia.edu

Highlights

- Focus on the urban planning and strategic policy documents related to climate change actions, i.e. adaptation or mitigation efforts, across 32 Italian cities.
- The mitigation actions contained in the climate plans are further investigated through cluster analysis to aggregate cities in homogenous groups in policy strategies and mitigation actions.
- We found that there are not clear geographic patterns of cities' responses across Northern and Southern regions or within large and small cities.
- The cities and their plans show different levels of ambition to reduce emissions (i.e. mitigation targets), reflecting the different political commitment of Italian local authorities.

1 Introduction

The awareness about the relevance of local actions in the field of climate change has led Italian cities to develop an increasing interest on topics related to sustainability. This process has resulted in the implementation of a number of instruments aimed to achieve urban sustainability, promoted by national and international actors. An example of this trend is the large number of Italian cities that have developed Local Agenda 21 processes (Coordinamento AGENDE 21 Locali Italiane, 2013). The path towards sustainability acting in the field of energy policy has been taken by several cities that present a strong background in energy planning and are members of the Covenant of Mayors (Covenant of Mayors, 2013a). Another relevant line of action common to many Italian cities are the Urban Traffic Plans (compulsory from 1995 for cities with a population of more than 30,000 inhabitants) and the Urban Mobility Plans (defined by the Government in 2000 to help cities planning their urban mobility model) that, among other objectives, have contributed to reduce emissions and energy consumption in urban areas.

In this context, along with the instruments mentioned, Italian cities have faced in the last decade the development of a specific climate policy through the definition and implementation of plans that aim at mitigating greenhouse gases and, in few cases, adapting to the impacts of climate change, although these policies were sometimes not particularly defined or named as such. The action undertaken so far is uneven and, among other factors, highly influenced by the environmental culture of the territories and the climate action undertaken by the regions and provinces.

Section III-3, drawing on Salvia et al. (2013), analyzes the contribution of Italian cities to climate actions. In particular, urban mitigation actions by Italian cities included in the Eurostat Urban Audit (UA) database (European Union Regional Policy, 2013) are analysed through Cluster Analysis to highlight similarities of cities responses in climate mitigation planning.

2 Urban climate actions in Italy

Urban climate action in Italy has occurred in a policy environment where policies and measures developed by the Central Government, Regions and Provinces have focused mainly on energy strategies, mainly related to mitigation issues (Gargiulo et al., 2012). Only recently, more emphasis has been given to adaptation issues. In 2007 the Ministry for the Environment, Land and Sea established the Italian National Conference on Climate Change (Conferenza Nazionale sui Cambiamenti Climatici, 2007), bringing together experts, politicians and stakeholders to discuss technical, economic and institutional issues related to climate change and their impacts. The results of the conference were included in two final documents containing guidelines for the establishment of a national strategy to mitigation and adaptation to global warming (ENEA, 2011). With the EU White Paper “Adapting to climate change: Towards a European framework for action“ (2009) Member States were invited to adopt a National Adaptation Strategy, providing a guide for the ongoing and future work on adaptation. In response, the Italian Environmental Ministry has embarked on the implementation of a National Adaptation Strategy to climate change (NAS) in 2012. NAS is currently in a public consultation, which will close by the end of 2013 and the implementation process should be completed early 2014.

Regarding mitigation, decentralization of functions and administrative tasks in the energy sector has delegated an important role in driving the reduction of greenhouse gas emissions to the Regions. To undertake this task all the Regions have translated the national objectives of CO₂ emissions reduction in strategies included in the Regional Energy-Environmental Plans (REEPs) during the period 1997-2010. These instruments mainly focus on energy efficiency and enhance the exploitation of renewable energy sources.

On the other hand, Italian provinces are developing a coordinating role for energy and climate policies at local scale as to provide technical and financial assistance to municipalities. In recent years many Provinces have become supporting structures of the Covenant of Mayors. An exemplary case is provided by the Province of Chieti which through an effective promotional campaign and with the technical support of the provincial agency for energy achieved the signature of the Covenant of Mayors by all the 104 mayors of the province which are now working hard to surpass the EU's CO₂ reduction target of 20 % by 2020 (Covenant of Mayors, 2013b). Nevertheless, only a few Italian provinces have identified their own specific climate change strategy. Recently, the Italian Local Agenda 21 Association together with the National Association of Italian Municipalities (ANCI) and the Union of Italian Provinces (UPI) have developed the Charter of Italian Cities and Territories for the Climate, which is expected to become a reference document for

the spatial policies in Italy putting climate planning into practice in the next few years through multi-level governance and cooperation also on climate issues (see e.g. Coordinamento AGENDE 21 Locali Italiane, 2012).

Cities play also a key role in implementing the guidelines set out by the planning tools at regional/provincial levels through Municipal Energy Plans (accordingly to the National Law 10/1991) and, more recently, by developing Sustainable Energy Action Plans (SEAP) as part of the Covenant of Mayors (CoM). As reported by Cerutti et al. (2013), Italy is the country with the highest number of signatory cities in Europe: 2582 signatories (as of 14th March 2013), followed only by Spain (1323 signatories) and France (only 151 signatories). A more detailed picture of the Italian participation to the CoM, in terms of urban population involved (average of the period 2008–2012) and SEAPs submitted is reported in Table 3.3.1.

Table 3.3.1 The signatories of the Covenant of Mayors and submitted SEAPs in Italy as of 14th March 2013 (based on Cerutti et al., 2013).

	Italy
Number of signatories	2,582
Percentage from the number of signatories	51.14%
CoM population by country 2008–2012 (thousands)	29,964
Percentage from CoM population	15.97%
Percentage covered by CoM from the country urban population	72.67%
Urban population (thousands) 2008–2012	41,233
Number of SEAPs submitted	1217
% of submitted SEAPs	46.83%
Population covered by SEAPs	17,960,954
% of the population from submitted SEAPs	16.31%
% of the country urban population covered by the submitted SEAPs	43.56%

Over the last 10 years climate actions included in specific plans are widely spread: there are cities that adopted a consistent vision and undertook early actions, and cities where climate policy has been piecemeal or almost non-existent. An overview of the plans, actions and initiatives undertaken so far by Italian cities on climate mitigation issues is provided below.

3 A database on climate plans for Italian cities

This study collected and analysed plans, actions and initiatives undertaken by selected Italian cities to tackle climate change. In addition to the climate plans analysed in Reckien et al. (this volume) we include here also sectoral plans which contain supportive mitigation initiatives and actions, such as municipal energy and energy efficiency plans as well as SEAPs that can have a strong influence on greenhouse gas emissions and (Table 3.3.2).

A first analysis of the Italian sample of the Urban Audit database shows an increasing commitment of Italian cities on energy-environmental and climate issues. In particular it can be observed a relevant and consistent participation of municipalities to European networking initiatives (e.g. Eurocities, Energy cities, Climate Alliance). A large number of Smart Cities initiatives are also arising on the national territory (interesting at least 24 municipalities in the sample both in the framework of internationally- and nationally-funded projects) as well as an increasing involvement in European Union funded programmes (e.g. INTERREG, LIFE, South East Europe). 24 out of the

32 analyzed cities are signatories of the Covenant of Mayors and 16 of them have already implemented their own Sustainable Energy Action Plan, which was considered a mitigation planning tool for those cities without more specific climate plans. Among these cities, Genova was the first in Europe to publish its ambitious and comprehensive SEAP on the Covenant of Mayors website, and Bari set a very ambitious target: a reduction of over 35% of CO₂ emissions by 2020 (compared to 2002). An overview of the cities' and their commitments in terms of reduction of CO₂ emissions is provided in Table 3.3.2.

For the remaining cities (without mitigations plans or SEAPs) energy plans were taken into account to assess their potential contribution in terms of mitigation strategies, although only in few cases (3 out of 7 plans) specific targets on the reduction of CO₂ or GHG emissions are defined. In this sample of cities (Table 3.3.2), besides the 16 cities that have developed a SEAP, 7 cities implemented an energy plan, 1 city set a specific program to promote solar source whereas the remaining 8 cities have not implemented yet any structured mitigation tool.

In general the analysis of mitigation plans reveals that the proposed actions and strategies are mainly focused on the exploitation of renewable energy sources (mainly PV and solar thermal), a rationalization of energy uses and the improvement of energy efficiency in buildings (household and public buildings - mainly schools), sustainable transportation and sustainable mobility (e.g. promoting "bike-and-ride" and "bike-lift").

Some plans are also introducing actions aimed to educate and raise awareness on energy consumption, and to promote citizens' participation in the implementations of the devised actions (especially regarding those oriented to energy saving). For example, some municipalities are using energy policies to relate climate change to everyday life, in terms of citizens' commitment and awareness raising.

The analysis shows also that there is a general delay in dealing with climate change adaptation at urban level in Italy whereas adaptation plans and initiatives are more frequently carried out at a higher administrative level (Province, Region). In particular, none of the analyzed cities has carried out a comprehensive adaptation plan, although some of them have expressed the intention to integrate adaptation measures into the existing mitigation plans.

Based on these findings, the following analysis focuses on an application of the Cluster Analysis on urban mitigation plans.

Table 3.3.2 Cities and documents analysed in the Italian Urban Audit database.

City	Abbr	Population (2012)	Covenant of Mayors	Mitigation strategy name	Local authority/Department in charge of Plan development	Year	CO2 target (%)	Target year (Baseline)
Ancona	AN	100,465	yes	Draft of Environmental Energy Plan (<i>Bozza di Piano Energetico Ambientale Comunale</i>)	Municipality of Ancona (Department of Environmental Policy)	2008	n.a.	n.a.
Bari	BA	315,408	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Bari (Department of Public work)	2011	35	2020 (2002)
Bologna	BO	371,151	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Bologna (Departments of Urban Planning, Economics, etc.)	2012	20	2020 (2005)
Brescia	BS	189,085	no	Energy Local Plan (<i>Piano Energetico Comunale</i>)	Municipality of Brescia (Settore Urbanistica)	2002	28	2006 (2002)
Cagliari	CA	149,343	yes	Programme for the Promotion of Solar Energy (<i>Programma per la promozione dell'Energia Solare</i>)	Municipality of Cagliari (Department of Environment and Territory)	2007	n.a.	n.a.
Campobasso	CB	48,675	yes	n.a.	n.a.	n.a.	n.a.	n.a.
Caserta	CE	75,625	yes	n.a.	n.a.	n.a.	n.a.	n.a.
Catania	CT	293,104	yes	n.a.	n.a.	n.a.	n.a.	n.a.
Catanzaro	CZ	89,319	no	n.a.	n.a.	n.a.	n.a.	n.a.
Cremona	CR	69,675	yes	n.a.	n.a.	n.a.	n.a.	n.a.
Firenze	FI	357,318	yes	Sustainable Energy Action Plan (<i>Piano di Azione per l'Energia Sostenibile del Comune di Firenze</i>)	Municipality of Firenze (Department of Urban Development)	2011	20	2020 (2005)
Foggia	FG	147,045	no	Municipal Energy Plan (<i>Piano Energetico Comunale</i>)	Municipality of Foggia (Department of Environment and Energy)	2007	n.a.	n.a.
Genova	GE	584,644	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Genova (Department of Environment and Energy)	2010	23.7	2020 (2005)
L'Aquila	AQ	66,905	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of L'Aquila	2011	20	2020 (2005)
Milano	MI	1,240,173	yes	Sustainable Energy and climate Action Plan (<i>Piano d'Azione per l'energia sostenibile e il clima</i>)	Municipality of Milano (Department of Environment)	2009	20	2020 (2005)
Modena	MO	179,095	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Modena (Department of Environment)	2011	20	2020 (2009)
Napoli	NA	961,106	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Napoli	2012	25	2020 (2005)
Padova	PD	205,631	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Padova (Department of Environment)	2011	20	2020 (2004)

Palermo	PA	656,829	no	Municipal Energy plan (<i>Piano Energetico Comunale</i>)	Municipality of Palermo	2000	10	2010 (1990)
Perugia	PG	162,097	no	Municipal Energy-Environmental Plan (<i>Piano Energetico Ambientale Comunale</i>)	Municipality of Perugia	2005	6.5	2010 (2000)
Pescara	PE	116,846	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Pescara	2012	22	2020 (2005)
Potenza	PZ	66,698	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'energia sostenibile</i>)	Municipality of Potenza	1997	22	2020 (2009)
Reggio di Calabria	RC	180,719	no	n.a.	n.a.	n.a.	n.a.	n.a.
Roma	RO	2,614,263	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Roma (Department of Environmental Protection, Green Areas and Civil Protection)	2011	20	2020 (2003)
Salerno	SA	132,741	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Salerno,	2012	20	2020 (2005)
Sassari	SS	123,624	yes	Preliminary document for the Municipal Environmental Energy Plan (<i>Documento preliminare per il Piano Energetico Ambientale Comunale</i>)	Municipality of Sassari (Department of Environmental Policy and Green Areas)	2011	n.a.	n.a.
Taranto	TA	199,936	no	n.a.	n.a.	n.a.	n.a.	n.a.
Torino	TO	371,151	yes	Turin Action Plan for Energy (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Torino	2010	40	2020 (1991)
Trento	TN	114,063	no	Environmental Energy Plan "Trento per Kyoto" (<i>Piano Energetico Ambientale del Comune di Trento</i>)	Municipality of Trento (Department of Environment)	2007	n.a.	n.a.
Trieste	TS	201,814	yes	n.a.	n.a.	n.a.	n.a.	n.a.
Venezia	VE	260,856	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Venezia (Department of Air Quality and Energy)	2012	20	2020 (2005)
Verona	VR	251,842	yes	Sustainable Energy Action Plan (<i>Piano d'Azione per l'Energia Sostenibile</i>)	Municipality of Verona (Department of Environment)	2012	20	2020 (2006)

4 Application of cluster analysis on urban mitigation plans

A statistical analysis of the information content of the database was carried out by Cluster Analysis (CA). This is a multivariate statistical technique for exploratory analysis widely used in environmental sciences and is useful to highlight associations and structures of the analyzed data. The aim is to identify a minimum number of groups such that the elements belonging to a group are more similar to each other than to the elements belonging to other groups.

Starting from the information gathered in the mitigation part of the database, a matrix of type [objects x descriptors] was built, where the objects are the cities analyzed and the descriptors are the topics included in climate change mitigation plans. In particular, an initial matrix of size [32 x 15] was built considering the number of the investigated Italian cities (32) and the number of the identified descriptors (15) as resumed in Table 3.3.3.

Table 3.3.3 List of the 15 analysed descriptors.

Analysed descriptors: topics included in the plans		
CO ₂ emissions target	Waste management	Agriculture
GHG emissions target	Urban planning	Transportation
Measure of energy efficiency	Intra-municipal reorganization	Industry
Renewable energies	Buildings	Commerce, trade, services
Heating from renewable energies	Jobs	Households

The data are qualitative as they indicate the presence or absence of the predefined topic in the plan. To this end, the number one is used conventionally to indicate the presence of a topic in the plan and zero to indicate the absence of a topic. After a preliminary qualitative analysis, the number of objects was reduced to 23 due to the fact that in nine cities (Campobasso, Caserta, Catania, Catanzaro, Cremona, Reggio Calabria, Sassari, Taranto and Trieste) all the 15 topics were absent.

In this analysis, for a matrix of size [23 x 15], a hierarchical agglomerative procedure was applied using the Sokal & Michener index (Sokal & Michener, 1958) as similarity measure and the algorithm of complete linkage. The Sokal & Michener index is defined in the following way (Eq. 3.3.1):

$$S_{ij}^{SM} = \frac{a + d}{a + b + c + d} \quad (3.3.1)$$

where the coefficients a, b, c, d represent the occurrence of the configurations 11, 10, 01 and 00 in the binary case, interpretable as presence or absence of a specific factor or characteristic.

The results obtained applying the cluster analysis to the Italian Mitigation database are shown by the dendrogram of Figure 3.3.1.

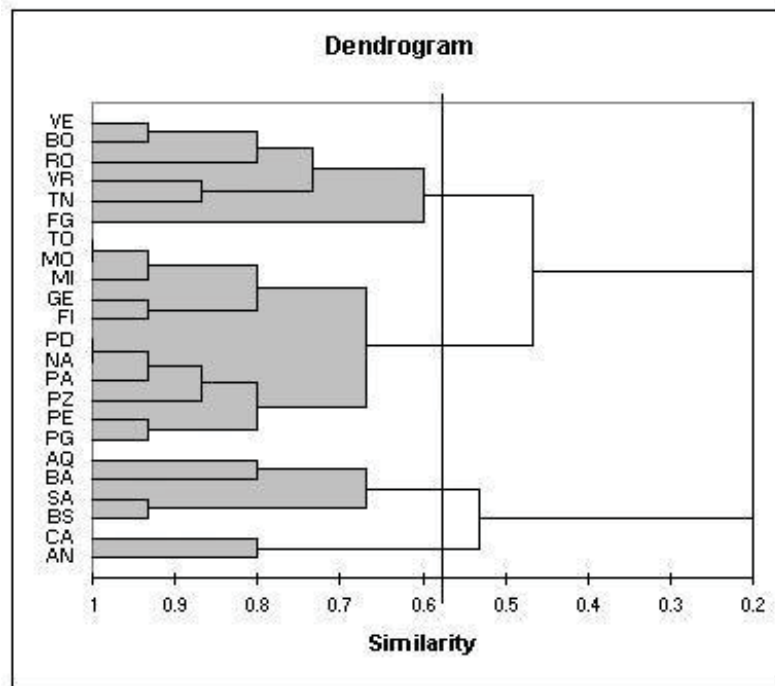


Figure 3.3.1 Dendrogram of cluster analysis using similarity index.

Cutting the dendrogram as shown in Figure 3.3.1 for a value of the similarity index close to 0.6, four clusters for the 23 cities can be identified, as described in Table 3.3.4. In particular, cluster 2 has two peculiarities: Modena (MO) and Torino (TO) as well as Padova (PD) and Napoli (NA) are represented by the same point on vertical axis. This is due to the fact that these cities are characterized by a similarity index of 1 since they have the same values for all topics.

Table 3.3.4: Main List of the 15 analysed descriptors.

Cluster 1 - good number of covered topics	Cluster 2 - very high number of covered topics	Cluster 3 - sufficient number of covered topics	Cluster 4 - very low number of covered topic
Cities that have implemented intra-municipal reorganization such as GPP-Green Public Procurement, investing in energy efficiency and promoting renewable energies (in the commercial sector and in households) but undertaking no action on waste management. This group includes the following 6 cities of Bologna, Foggia, Roma, Trento, Venezia and Verona	All cities have set CO2 reduction targets, dealing with energy efficiency, renewable energies (both for electricity and heat production), waste management, urban planning and transportation. In this cluster are gathered the following 11 cities of Firenze, Genoa, Milano, Modena, Napoli, Padova, Palermo, Perugia, Pescara, Potenza and Torino.	Cities have not developed any actions as concerns agriculture, intra-municipal reorganization and jobs interventions. The proposed initiatives involve commerce, trade and services. As cluster 2, all cities have set CO2 reduction target. This cluster includes these 4 cities of Bari, Brescia, L'Aquila, and Salerno.	Cities that have a very low number of topics included in their plans, respectively two (transportation and buildings) and three (renewable energies, heating from renewable energies and buildings) and may not have not CO2 reduction targets as is the case with the 2 cities of Ancona and Cagliari.

Figure 3.3.2 shows that there are no clear geographic differences between Northern or Southern cities' or between large and small cities. The analysed cities show different levels of ambition of mitigation commitments illustrated by the number and variety of the proposed actions (mitigation topics). The observed differences in cities' paths reflect the different political make-up and commitment of Italian local authorities in the latest years.

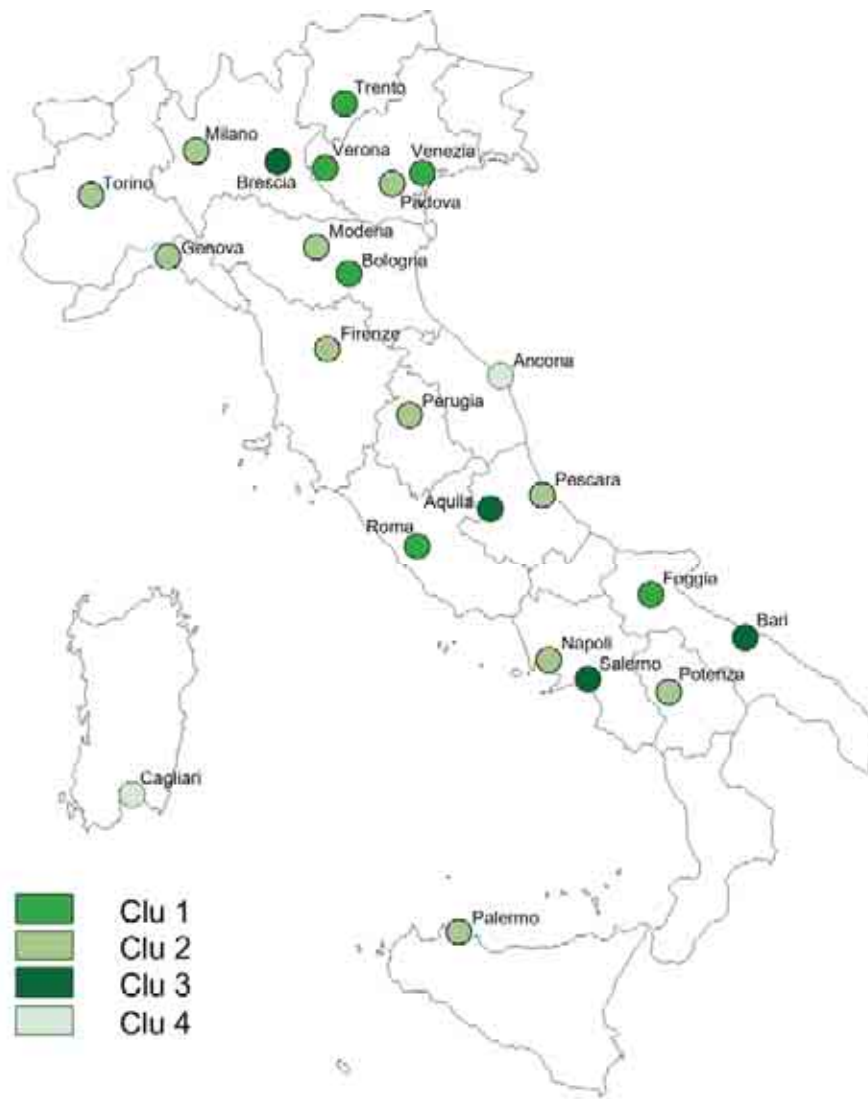


Figure 3.3.2 Geographical representation of cluster aggregations as concerns mitigation efforts in Italian cities (shadow areas represent the provinces of which the cities are capital, for a better graphical representation).

5 Conclusions

The analysis undertaken shows that the 32 Italian cities included in the Urban Audit database have focused their activity in the field of climate change policies in the definition and implementation of mitigation measures.

Italian cities are only partially playing the role they should to face the challenges and opportunities climate change may bring. Local action seems to have been hindered by the lack of guidelines (for example Italy is still concluding the preparation of a national adaptation strategy) as well as by the scarce coordination of the climate action undertaken by the different tiers of government. The present socio-economic situation at national level, that has caused a decrease of the financial resources devoted to the implementation of local policies, is another relevant limitation.

Results show that even if most of the 32 cities have not developed structured mitigation plans yet, a majority of them have become active to mitigate climate change, first of all, through the development of municipal energy plans. Moreover, the membership to the Covenant of Mayors, which has boosted the development of Sustainable Energy Action Plans intended as plans of energy

efficiency and climate action, is a relevant potential driver of transformation of the approach that cities have assumed so far regarding climate policy.

Therefore, positive consequences can be observed at urban level in terms of promotion of renewable energies, implementation of energy saving and energy efficiency measures in different fields (e.g. transportation and households) as well as intra-municipal reorganization. Common behaviours in relation to how these cities address mitigation issues in their plans are effectively pointed out by cluster analysis. We have shown how “clusters” of cities are moving less or more homogenously towards a more sustainable and climate resilient configuration.

It is self-evident that planning for mitigation and adaptation in Italy and elsewhere is a dynamic process. More and more cities are engaging in climate actions although only a more comprehensive, coherent and structured interaction between cities, provinces, regions and the national government can assure successful and comprehensive climate action in the medium to long term.

Acknowledgements

This sub-section is based on Salvia, M et al. (2013) Urban responses to climate change in Italy. Proceedings of the 3rd International Exergy, Life Cycle Assessment & Sustainability Workshop & Symposium - ELCAS3. Nisyros Island, Greece, 7-9 July 2013. Edited by: Koroneos Christopher, Rovas Dimitrios & Dompros Aris. pp. 705-722. We would like to thank Nicola Afflitto (CNR-IMAA) for his kind help in editing Figure 3.3.2.

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Box III-2: Modelling atmospheric and aqueous emissions in Riga

Eugene A. Kopytov¹, Sharif E. Guseynov

¹ *Transport and Telecommunication Institute, Riga, Latvia, E-mails: kopitov@tsi.lv*

Latvia takes 21st place among 163 countries in the world by the purity of the environment (Environmental Performance Index, 2010). Nevertheless, Latvia has serious ecological problems related first to the Baltic Sea health and second to the urban air pollution caused by transport and energy sectors, which is particularly heavy during windless or cloudy weather.

This textbox is based on our research paper (Guseynov and Kopytov, 2012), where we proposed complex qualitative models that use dynamic parameters for analysis, evaluation and forecast of aquatic (water reservoirs, lakes and the Baltic Sea) and atmospheric pollution. In this research, using integrated assessment methods (see also Koehler et al. this volume), we have combined five environmental models for the urban area of Riga (Latvia): 3 models for aquatic ecosystem (1-3) and 2 urban atmospheric pollution (4-5) as described below:

1. Pollutant concentration dynamics qualitative model applied to the "layered in respect to depth" Baltic Sea at a known velocity of pollutant transfer. This model can be used as the primary model for monitoring pollution concentration within the Baltic Sea;
2. Multi-component dynamic model for determining the main characteristic for the process of the substance circulation (taking circulation of nitrogen as an example) in the near-surface layers of the natural aquatic environments (natural reservoirs, large basins, lakes and seas);
3. Model for determining sensitivity of oxygen conditions for the Baltic Sea;
4. Non-stationary model for determining the dynamics and concentration of hazardous substances in the turbulent urban atmosphere with unknown velocity of air flow;
5. Molecular-kinetic complex model of distribution of hazardous substances for multi-layered computation domain of sophisticated configuration taking into account the wind field and urban area development (i.e. quasi-hilly landscape).

In order that all these proposed models are operational and applicative, it is necessary to collect and process various data affecting the ecosystem. For instance, to activate the urban-environmental models (models 4 and 5) the following data are required: urban traffic flow intensity and street structure, the field of wind velocities over the area of the complex terrain; coefficients of vertical and horizontal turbulence; characteristic height of the mixing layer, within which there is an intensive process of pollutant transfer in the atmosphere; wind velocity; height of the upper boundary of the mixing layer; the flux level of deposition; class of atmospheric stability; temperature gradient. Besides, it is important to emphasize that all the required initial data are available and can be relatively easily acquired by means of using meteorological equipment.

Using these models, we can provide more precise data on the pollution, abatement costs and efficiency, which enables decision makers to determine the scale of the problems and select the appropriate solutions. The developed models were implemented as a set of computer programs, involving the application software package MathCAD and C/C++ programming language. We tested them using various case studies; and the simulations matched real life statistical data.

One of such examples is shown in Figure B3.2.1 (Fradkin, 2012). Here the concentration of hazardous substance NO is calculated through one of the urban-environmental models (No. 5). Statistical data describes the urban traffic flow intensity and street structure (K. Valdemara Street in Riga) and the concentrations of substance NO (7th Feb. 2005) have been used to compare these with

the results from the model (dotted line in Fig.1). The concentrations are measured at the height of 2.5 m (the height of the measuring station). As one can see from the graphs, the mathematical model reflects the observed concentration of harmful substance very closely indeed.

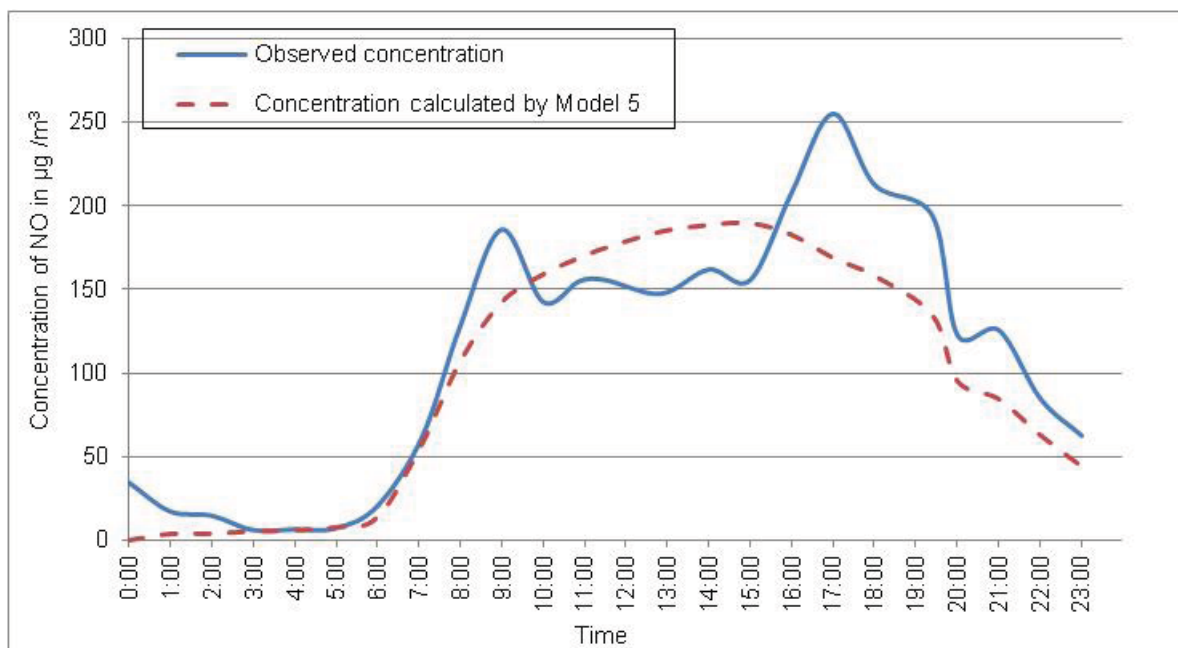


Figure B3.2.1 Observed and calculated concentrations of NO in the area of motor traffic, K. Valdemara Street 18, Riga, 7th February, 2005.

The proposed models are described in terms of differential equations theory (using both ordinary differential equations and partial differential equations) and are regarded to be the evolutionary models. More details of the mathematical approach and the integration of assessment models for the analysis, evaluation and prediction of emissions can be found in our recently published research paper (Guseynov and Kopytov 2012). Also more details on integrated modelling in general and across disciplines can be found in Koehler et al. (this volume). Our research will continue as we investigate and determine further the benefits of both qualitative and quantitative studies for all five models. It also includes the development of the stable analytical and numerical methods for their solution, ensuring that the corresponding computer-based implementation can be provided to the decision maker and therefore acting as a truly integrated assessment tool in urban areas.

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Section III-4

Multi-level climate governance and urban climate action

Sonia De Gregorio Hurtado¹; Marta Olazabal², Monica Salvia³, Filomena Pietrapertosa³,
Efrén Feliú⁴, Eduardo Olazabal⁵, Davide Geneletti⁶, Valentina D'Alonzo⁶,
Senatro di Leo³, Diana Reckien⁷

¹*Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, Av.de Juan de Herrera, 4, 28040 Madrid, Spain; sdegregorio@mailpersonal.com*

²*Basque Centre for Climate Change (BC3), Alameda de Urquijo 4, Bilbao 48008, Spain; marta.olazabal@gmail.com*

³*National Research Council of Italy - Institute of Methodologies for Environmental Analysis (CNR-IMAA), C.daS.Loja; 85050 Tito Scalo (PZ), Italy; monica.salvia@imaa.cnr.it; filomena.pietrapertosa@imaa.cnr.it; senatro.dileo@imaa.cnr.it*

⁴*Tecnalia, Parque Tecnológico de Bizkaia, c/ Geldo, edificio 700, 48160 DerioBizkaia, Spain; efren.feliu@tecnalia.com*

⁵*Universidad de Zaragoza, C/ Pedro Cerbuna, 12, 50009 Zaragoza, Spain; eduardo.olazabal.salgado@gmail.com*

⁶*Dept. of Civil, Environmental and Mechanical Engineering- University of Trento, via Mesiano, 77 38123 Trento, Italy; davide.geneletti@unitn.it*

⁷*Center for Research on Environmental Decisions, Columbia University; 406 Schermerhorn Hall – MC5501, 1190 Amsterdam Ave., New York, NY 10027, U.S.A.; dianareckien@columbia.edu*

Highlights

- Explores causes and consequences of the influence of multi-level climate governance, i.e. interaction and integration of climate action developed by the different tiers of government (national, regional and local) in two EU countries: Italy and Spain.
- Conclusions are drawn based on detailed compilation, review and analyses of climate change policies, strategies, plans and implementation programmes of 32 Italian cities and 26 Spanish cities.
- The research identifies the importance of constructing collaborative multi-level climate frameworks at the national scale, that fully integrate the local level, in order to support cities to develop consistent climate action and raise awareness of the responsibility they have in this policy field.

1 Introduction

Global impacts of climate change pose serious threats on cities. At the same time, cities are responsible for a relevant share of the emissions inducing climate change (Dhakal, 2010). This identifies cities as crucial stakeholders that need to address adaptation and mitigation to climate change through sound integrated urban policies in collaboration and with the support of the upper levels of government in their respective national contexts.

The competency and capacity of local governments to address this crosscutting policy field is largely determined by the institutional and legal structures in which they are embedded (Shroeder

and Bulkeley, 2009). The relationship between the different arenas of authority is considered critical in shaping the global capacity to govern climate change (UN-Habitat, 2011). Generally, the pro-action and reaction to climate change has been characterized by a top-down approach, as national governments and regions play the key role in developing regulations, agreements, commitments and medium and long term plans. Cities have so far rarely had a determinant influence on the national climate governance frameworks in Europe. However, the changing political and institutional contexts during the last decades of the 20th Century in Western Europe resulted in an increase of the interdependency between the different tiers of government, as many national responsibilities have been gradually devolved to the regional and municipal levels (Hopkins, 2002).

In this context, Section III-4 aims to provide an understanding on how multi-level climate governance, i.e. interaction and integration of climate action developed by the different tiers of government (national, regional and local) influence the climate change capacity and performance of cities. This is achieved by focusing on two EU national contexts: Italy and Spain. For this, two complementary assessments have been performed: (1) An assessment of the institutional multi-level governance structures and policies in the field of climate change, and (2) an assessment of local climate change adaptation and mitigation plans. The reasonably similar conditions under which climate change policy is being developed in Italy and Spain allows comparing how governance structures and approaches influence urban climate action in these and potentially other EU countries.

2 Data and method

Spain and Italy have been selected as they present relevant similarities in terms of climate vulnerabilities, urban configurations, institutional architecture (based on four levels of government –central or national government, regions, provinces and cities) and degree of devolution to the local tiers. The analysis is two-fold:

- 1) *Analysis of multi-level governance* regarding climate change. Here, we compiled and analysed climate policies and collaborative instruments and actions that were developed by different tiers of government in order to induce multi-level collaboration for climate action. The main sources used are: (i) institutional and legislative documents, scientific and grey literature and (ii) email exchange, conversations and interviews to experts and stakeholders (see De Gregorio et al., 2014 for further details in the document selection).
- 2) *Understanding urban climate action*. The analysis focused on a sample of 32 Italian and 26 Spanish cities that are listed in the Eurostat (2013) Urban Audit (UA) database (Figure 3.4.1). This work uses the method described in Reckien et al. (this volume) and Reckien et al. (2014) and extends it by including mitigation and mitigation-related and adaptation and adaptation-related plans (see Olazabal et al., 2014 for further details).

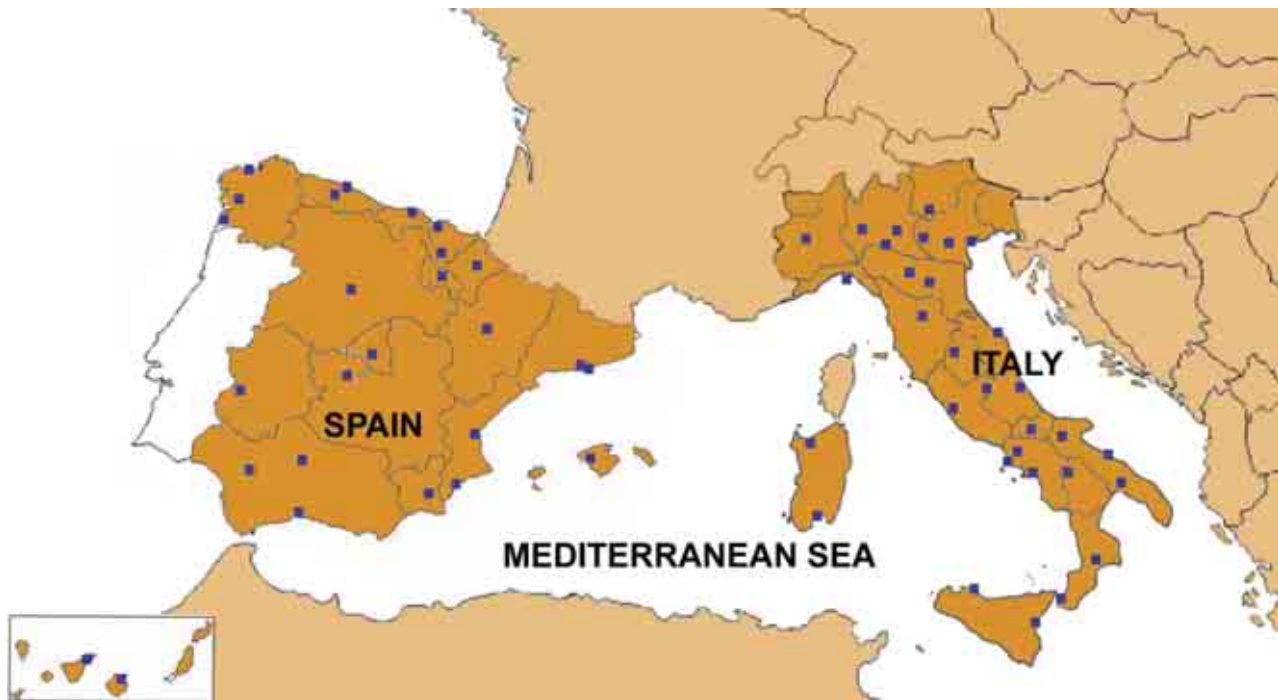


Figure 3.4.1 Italian and Spanish cities analysed.

3 Climate policy and multi-level governance in Italy and Spain

3.1 Climate policy and multi-level governance in Italy

Italy is organised in four governmental tiers: National Government, regions, provinces and municipalities. The institutional system of the country assigns to the 20 existing regions a status that enables them to enact laws that regulate the governmental action of the provinces and municipalities. In this sense the literature considers that Italy has assumed a government form typical of the federal systems, where each region develops legislation in those matters not reserved to the federal state (Lefèvre, 2012; Casetti, 2004). Within this general framework the regions and the local governments have assumed important competences since the end of the 1990s. Energy and environmental issues have been transferred to the regions. This fact, together with the regional strength in terms of financial resources, has resulted in the regional level playing a pivotal role in the national climate policy.

The climate change policy of the country has been developed within the framework of the mentioned transfer of government responsibility and legislative power to the regional, provincial and municipal governments. It is resulting in the introduction and consolidation of a policy area that, as in many other EU countries, is currently taking form assuming inertias and being influenced from traditional policy styles and outlooks of key policy makers (Marchetti, 1996). It is recognized that the National Government in Italy has delayed action regarding climate change (Marchetti, 1996) compared with other industrialized countries. This has negatively affected the action developed by the lower levels of government (OECD, 2013).

As a first explicit step to develop a national climate policy, in 1994 Italy approved the National Plan for the Containment of CO₂ Emissions. Three years later, in 1997, the country signed the Kyoto Protocol, committing to reduce its greenhouse gas emissions by 6.5% below the base-year levels (1990) over the first commitment period, 2008-2012. The overall responsibility for meeting the targets agreed in the Kyoto Protocol is with the National Government, and there are no specific

legislative arrangements and enforcement/administrative procedures at the regional level to meet those. However, considering that in other sectors, such as the energy production and transport, the regions have legislative powers, a number of policies relevant to greenhouse gas emission reduction have been enacted at the regional level.

One year after the adoption of the Kyoto Protocol the National Plan for the reduction of GHG emissions was approved. The Plan abandoned the sectoral approach of the 1994 Plan, giving place to a concerted effort of all Ministries and other administrative authorities relevant for the achievement of GHG reduction. The next National Plan for the Reduction of greenhouse gas emissions (2003-2010) (Ministero dell'Ambiente e Tutela del Territorio, 2002) was approved in 2002 and has the main objective of achieving the country's commitment under the Kyoto Protocol defining a set of policies and measures mainly aimed at increasing energy efficiency and fostering the use of renewable energy sources.

Also in 2002 the Italian National Climate Change Strategy was approved (CIPE deliberation 123/2002), aiming at increasing energy efficiency and the use of renewable energy. It also established an inter-Ministerial Technical Committee (CTE) to monitor the emissions trend and the implementation of policies identified in the national strategy, and to identify further measures to meet the Kyoto Protocol target. The transversal nature of the CTE points it out as a relevant instrument to improve interdepartmental governance at the Central Government level and to mainstream climate change into the relevant national policy fields.

Italy has recently drafted a new National Plan to reduce greenhouse gases (CIPE resolution n. 17 of 8 March 2013) that aims to prepare a pathway towards a decarbonisation economy in compliance with the European 2020 policy and the Energy Roadmap 2050. In this plan, Italy commits to contribute to the achievement of the EU's decarbonisation objectives: a 25% GHG reduction by 2020 with respect to 1990 level, 40% by 2030, 60% by 2040, and 80% by 2050.

In February 2012 Italy also started the development of a National Strategy for Climate Change Adaptation (NAS). At present a draft of the National Strategy is available to public consultation until the end of December 2013. Even if Italy does not have its own adaptation strategy yet some adaptation measures have been implemented in the context of natural hazards prevention, environmental protection, sustainable management of natural resources and health protection. The mentioned legislation and policy instruments developed by the National Government do not specifically address cities as relevant actors in climate policy. The Italian scenario shows that the climate action developed by the Central Government has not included a line of policy oriented to enhance climate initiatives at the local level nor that it has launched collaborative arenas where national climate action could be discussed.

Concerning the regions, many regional laws have been promulgated in Italy to govern territorial energy planning with detailed measures on renewable energy sources, energy saving of buildings and rational use of energy. Less emphasis is generally given to the opportunities offered by the transport sector in reducing emissions (Gargiulo et al., 2012). Moreover, in recent years more and more importance has been given to the sustainability of energy systems, the environmental (and climate) value of energy policies, and the relationship between the ways how energy resources are used and the consequent level of greenhouse gas emitted by energy supply and demand. In this respect, regions have translated the national and European objectives of CO₂ emissions reduction to the Regional Energy Plans, which have therefore become Regional Energy-Environmental Plans

(Piani Energetico Ambientali Regionali - PEARs). To date, all regions have approved their PEAR (ENEA, 2011).

Most of Italian regions have not developed yet regional climate change (mitigation or/and adaption) plans. As a result they have concentrated their action on energy planning (with important consequences in terms of mitigation measures) but not on the development of holistic climate plans, which have resulted in the lack of guidance for the stakeholders (institutional and non-institutional) that operate in their territory in those policy fields in which climate change can be mainstreamed.

The Italian Local Agenda 21 Association together with the National Association of Italian Municipalities (ANCI), the Union of Italian Provinces (UPI), and the regions have recently developed the “Charter of cities and territories commitments to climate protection” aiming at becoming a reference for spatial policies (Coordinamento Agende 21 Locali, 2009). In this document the municipalities, provinces and regions of Italy declare their intention to adopt integrated policies and actions for adaptation and mitigation of climate change acting on the basis of an integrated approach covering different fields, such as urban planning, energy planning, urban and metropolitan mobility, sustainable management of public facilities, etc. The objective is to reduce at least by 20% the greenhouse gas emissions and increase the balance within social, environmental and economic development of the territory. Signatories of the Charter commit themselves to carry out (within one year after signing) a Climate Plan that provides mitigation and adaptation actions. This Charter constitutes the most explicit way in which regions and provinces have recognized the importance of working with the municipalities to address climate change in their respective territories.

The review of the government activity developed by provinces in Italy in the field of climate change shows that they are playing a relevant role to support medium and small cities in energy/climate planning and to transfer the knowledge on climate action. Some provinces have developed their own specific climate strategy (mitigation and/or adaptation) and most of them are acting as coordinators for energy and climate policies at local scale.

3.2 Climate policy and multi- level governance in Spain

Spain is governed under a parliamentary monarchy with a high level of decentralization and devolution to the regional governments of the 17 regions (Autonomous Communities, AC hereafter) and the municipalities. There are four levels of government: the Central Government, the AC, the provinces and the municipalities. The Constitution guarantees the autonomy of the last three levels, but their autonomy is not of the same nature: on the one hand provinces and municipalities are local tiers of government with administrative autonomy, which basically means that they are responsible for the development of secondary legislation and the management of urban public services. On the other hand Autonomous Communities have real political autonomy, with legislative power on a relevant number of issues guaranteed by the Constitution (Parkinson et al., 2012).

Spain ratified the Kyoto Protocol in 2002, committing itself to limit greenhouse gas emissions by 15% if compared to 1990 for the period 2008-2012. Since then the Central Government started to develop the country's climate change policy implementing, particularly from 2004, a collaborative vision through the creation of various arenas of dialogue and collaboration. It aimed to assure the involvement of all relevant tiers of government in the fulfilment of the Spanish climate change objectives. The different arenas have different, particular tasks and achieved a relevant role in supporting the Central Government regarding climate decision-making. Meanwhile, the Central

Government has approved a number of documents and strategies that have contributed to set the basis on which the institutional climate governance approach has been taking form. In 2007 it passed the Spanish Strategy on Climate Change and Clean Energy (EECCEL) as part of the Spanish Sustainable Development Strategy (EEDS). One of its objectives was to provide the reference of coordination for the climate change policies of the State, the regions and the cities.

The National Plan for Adaptation to Climate Change (MMA, 2006) has been instrumental in the development of climate adaptation action in the country so far. This instrument responded to the high vulnerability of the Spanish territory to the adverse effects of climate change by providing a reference framework for the coordination of the Public Administrations in the activities of impact assessment, vulnerability studies, and adaptation to climate change. In order to give place to administrative coordination regarding adaptation to climate change, the Working Group on Impacts and Adaptation was created in 2007. The main aim of the instrument is the coordination and integration of the adaptation action of the Central Administration, the AC and the local level.

In 2005 the Government created the Spanish Network of Cities for Climate (RECC) with the objective of fostering the development of local policies to fight climate change through the adoption of 5 main axis of action: mobility, building, urban planning, energy and waste. The network was subsequently integrated in the vision and objectives of the EECCEL of 2007. The Central Government has also developed a policy to promote the development of mitigation measures by cities through the provision of funding to implement previously defined policies, the most relevant instrument has been the Energy Saving and Efficiency Strategy Spanish Action Plan (E4), approved in 2005 and implemented with a high level of involvement of the AC.

In Spain the AC are implementing a relevant number of mitigation measures, which were formerly adopted by the Central Government for diverse sectors⁷. The measures are adapted to the particular circumstances of the AC and, in most cases, complemented with others. Almost all the AC have formalized their climate action through the development of a climate change strategy and the creation of specific entities to deal with energy matters. The present situation shows that 16 out of the 17 Autonomous Regions have developed their climate change strategy or plan and the one left is currently developing it (Asturias). It is worth noting that most of them have approved their climate plans during the period 2007-2008 (the same in which the Central Government launched the EECCEL). They are usually mitigation plans that include in some cases adaptation measures. The review of those plans reveals that only in exceptional cases cities are enhanced to prepare their own mitigation or adaptations plans. In most cases the plans adopt a sectoral approach, providing guidelines to be implemented in different fields (housing, mobility, energy, public administration, etc.) and do not ask urban areas to implement a holistic climate action, but actions in the mentioned fields.

In general, the AC understood their role within this field of policy as a shared task with the Central Government in order to fulfil the national goals. The creation of coordination arenas between the Central Government and the regions has been a relevant factor that resulted in awareness and action of most of the regions regarding this matter.

Provinces are supporting the action of cities mainly in the areas: i) climate change policy, ii) energy management, iii) spatial planning, iv) waste management, v) urban and metropolitan mobility management, and vi) training and education. Another field where provinces are developing

⁷Transport, commercial sector, housing, institutional sector, agriculture and stockbreeding, and waste.

significant action is the development of networks of cities in their respective territories, with the aim of sharing knowledge and to give place to coordinate policies (RECC, without year). Even if it is not the rule, some provinces have developed their specific strategy on climate change. The role developed by the Spanish provinces can be considered relevant to foster climate action in medium and small cities.

4 Local climate actions in Italy and Spain

4.1 Italian local climate action

The 32 Italian UA cities⁸ in our sample cover 18.3% of the Italian population (ISTAT 2013). Regarding the specific efforts by these cities, 25% of them have not yet developed mitigation plans whereas the great majority has developed plans that are already approved and published. Those which set emission reduction targets (see Figure 3.4.2) often follow the EU goals and can lag behind other European cities (Reckien et al., 2014). Torino (with the objective to reduce CO₂ by a 40% by 2020), Bari (on a 35% by the same year), and also Brescia (that in 2002 committed to reduce by a 20% its emissions by 2006) are the cities with the strongest evidence of serious commitments (see Figure 3.4.2).

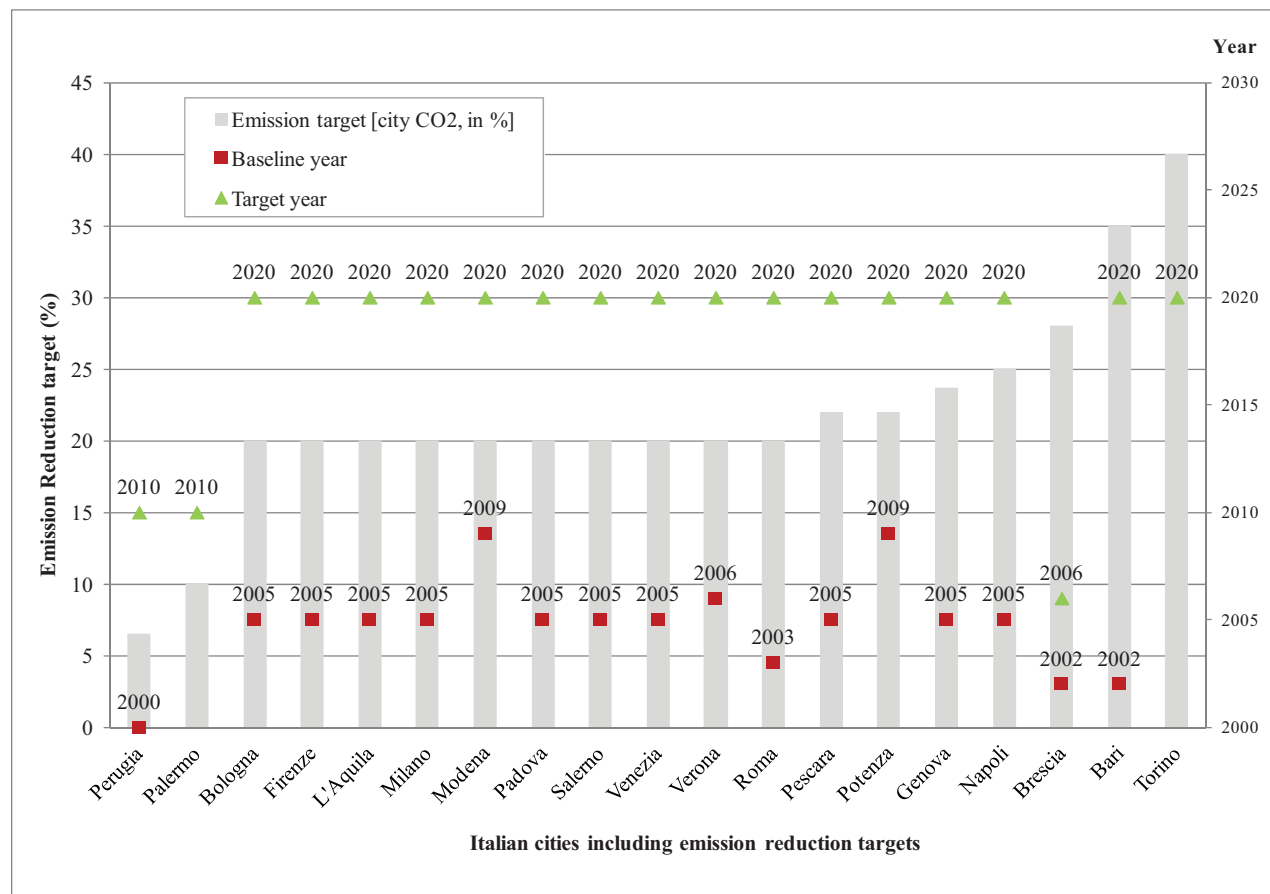


Figure 3.4.2 Emission reduction targets in selected Italian cities.

⁸ Ancona, Bari, Bologna, Brescia, Cagliari, Campobasso, Caserta, Catania, Catanzaro, Cremona, Firenze, Foggia, Genova, L'Aquila, Milano, Modena, Napoli, Padova, Palermo, Perugia, Pescara, Potenza, Reggio di Calabria, Roma, Salerno, Sassari, Taranto, Torino, Trento, Trieste, Venezia, Verona,

With regards to adaptation to climate change, the vulnerability index developed in the project ESPON-Climate (ESPON et al., 2011) points out that 84% of the Italian cities in our sample have an index of 4 or more, being 1 equal to “low vulnerability” and 5 equal to “high vulnerability”. Despite this high vulnerability, only 11 out of 32 cities included in this study have developed strategies that are related or have influence on the improvement of the adaptive capacity of the city to climate change. Only one of these plans (Mitigation and Adaptation Plan of Padova) was designed with the purpose of addressing adaptation issues specifically). The topics most often included in adaptation plans are: health (in plans related to heat and hydrological risks), forest management and urban planning (regarding building codes, urban greening and urban design)

4.2 Spanish local climate action

The 26 Spanish UA cities⁹ analysed in this work represent around 27 % of the population of the country (INE, 2012). The majority (54%) of them have approved their mitigation plans. Almost a quarter (23%) is in the process of developing the plan and 23 % have no intention to do so in the short term (according to personal communication of the city officers to the research team).

Cities including emission targets are shown in Figure 3.4.3. Bilbao and Zaragoza are the most ambitious cities with a target around 30% of CO₂ reduction. Most of the cities have contented themselves setting a reduction target of 20%. Madrid set a target of 14% greenhouse gas reduction until 2012 and it is expected that in the following plan a more ambitious target is set (personal communications).

As regards adaptation to climate change, the vulnerability index developed by the ESPON-Climate project (ESPON et al., 2011) points out that 84% of the cities have an index of 4 or more, being 1 equal to “low vulnerability” and 5 equal to “high vulnerability”. Despite this high level of vulnerability, only 7 cities out of 26 (27%) studied for this work have developed strategies to adapt to climate change. Among the adaptation plans, only 1 is published and approved (Zaragoza) and the other 2 are in early stages by either compiling information (Barcelona) or developing the diagnosis phase (vulnerability assessment and scenarios analysis), so the measures have not been defined yet. The topics covered by the adaptation strategies show that water issues, flood management as well as health and ecosystems management are the topics most looked at when designing strategies to adapt to climate change.

⁹Alicante/Alacant, Badajoz, Barcelona, Bilbao, Córdoba, A Coruña, Gijón, Las Palmas, L'Hospitalet, Logroño, Madrid, Málaga, Murcia, Oviedo, Palma de Mallorca, Pamplona, Santa Cruz de Tenerife, Santander, Santiago de Compostela, Sevilla, Toledo, Valencia, Valladolid, Vigo, Vitoria/Gasteiz, Zaragoza.

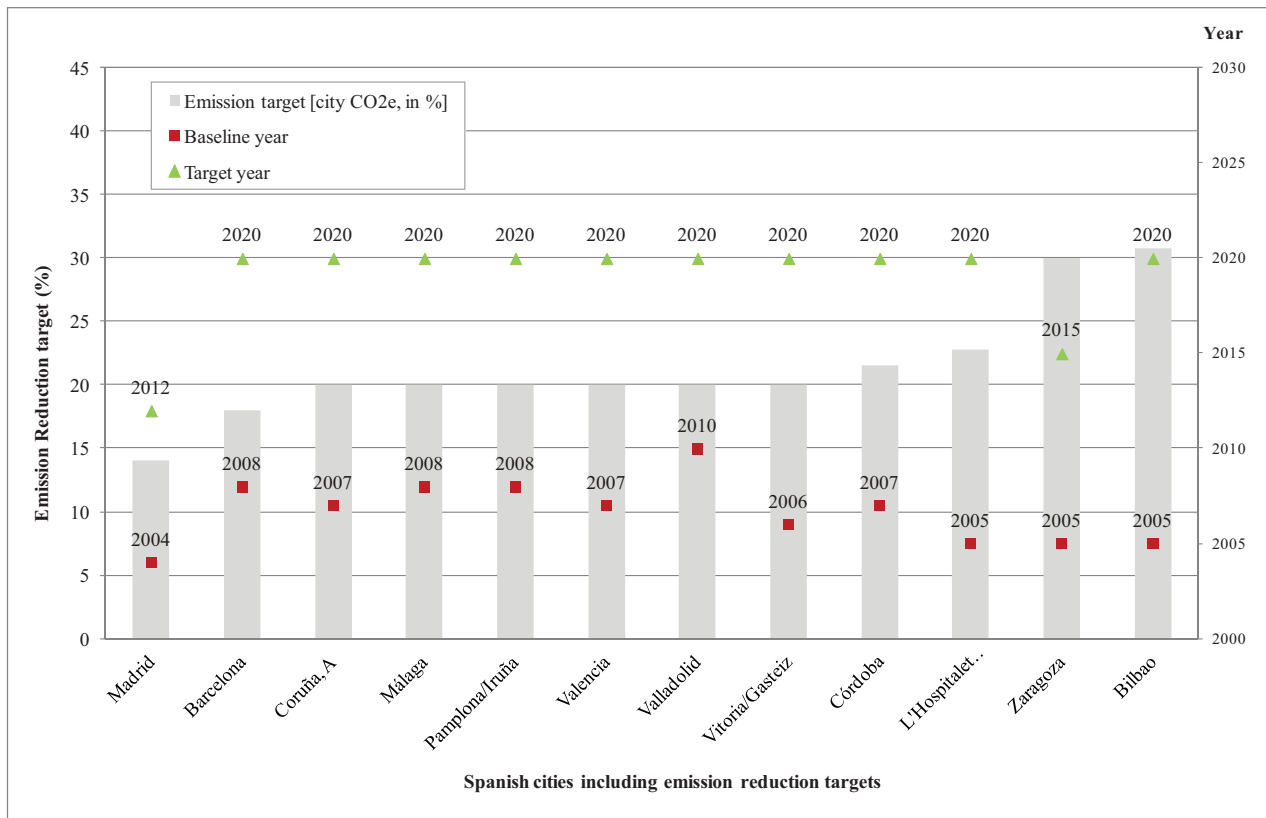


Figure 3.4.3 Emission reduction targets in selected Spanish cities.

5 Discussion

We demonstrated that local climate actions in Italy and Spain are comparable. In general, Italian and Spanish climate action is quite advanced with respect to mitigation, although it started earlier in Italy than in Spain (Olazabal et al 2014). However, the targets set by Italian and Spanish cities are not generally very ambitious if compared with other European cities (Reckien et al 2014). The analysis of the adaptation plans concludes that adaptation to climate change is not a frequent topic of the policy agendas of Spanish and Italian cities in spite of the evidenced high levels of vulnerability that characterise the cities studied (ESPON et al., 2011). Remarkably, Italian cities mostly address specific risks and develop plans accordingly, instead of developing integrated climate adaptation plans. On the contrary, the few Spanish cities that have developed adaptation plans have done it in an integrated way.

In Italy, the climate action of the National Government has been limited by the institutional framework, the competence distribution, and specific inertias of the Italian reality. This had a direct impact in the way in which the regions have developed their climate policy so far. They have not provided guideline frameworks for climate action for their territories, and for the stakeholders that operate within it. Thus, cities have proactively struggled to develop policies in line with the orientations provided by the EU and the best practices at urban scale provided by some EU countries during the last decade. Cities have increasingly become aware of the importance of this policy area, giving place to local initiatives.

During the period 2004-2011, the Spanish Central Government has acted by providing a framework of reference for climate mitigation and adaptation. During this period, a number of institutional arenas to support decision-making were created and the involvement of the regions was set as an explicit objective (to be achieved in order to be able to fulfil the national mitigation and adaption

goals). The engagement of the cities was set as an objective as well, but less direct action was developed to engage them in this policy area (due to the lack of competences on urban matters of the Spanish Central Government). The action developed by the Central Government from 2004 has contributed to introduce climate policy in the institutional agenda of the AC, with more commitment and attention from the regional level to mitigation than to adaptation. Today 16 out of 17 AC have approved their climate change strategies. The arenas of collaboration created during the 2000's have proved to play a relevant role in involving the regions in the national climate policy from the beginning. It is worth noting the interest the Central Government had to involve provinces and particularly cities in the national climate policy. The interest of the Central Government to influence local action has been a characteristic of the period 2004-2011 in many policy fields in which it does not have direct competences (urban planning, urban regeneration, urban and metropolitan mobility) (De Gregorio, 2013).

Overall, in the Spanish case the efforts made by the Central Government regarding mitigation have delivered relevant results in the case of the AC, and the provinces, but less so in the case of municipalities. One of the reasons seems to be the lack of explicit action by most of the AC to engage cities in their climate action and through demanding the development of specific climate plans at the municipal level. In fact, the review of the regional plans shows that in general the AC have transposed the Central Government's guidelines to the local level following the State approach, but they have not introduced in that approach the territorial vision that is inherent to the regional level (that entails understanding that different areas of the territory, such as cities, have to face climate change in a different and specific way). In general, there was no reflection on the role of cities in the regional climate policy. This fact shows a relevant weakness in the collaborative framework for climate change constructed from 2004 in the Spanish contexts. Another reason for the limited action of the AC in implementing the Central Government's vision to involve cities in climate policy is the institutional fragmentation that characterizes the Spanish context.

6 Conclusions

Regarding the effect of the multi-level governance on cities, this study shows that Italy has not created a climate policy framework based on the collaboration of the different levels of government (political, technical, and financial), that could have favoured the enhancement of urban climate action. In the Spanish case, the favourable scenario created by the Central Government in order to involve all the levels of government in the national climate policy (including cities) has not delivered the expected outcome, as it has not been successful in building a framework (based on a collaborative approach) to enhance urban climate action in the context of the national climate strategy.

Interestingly, recognising the explicit interest of the Spanish Central Government to foster urban action, with a big effort developed during the period 2004-2011, the limitations of the multi-level governance framework to integrate cities effectively in the national climate policy has delivered similar results than those of the Italian case where no action had been undertaken in this regard. In both countries cities have developed their climate plans and complementary actions generally based on their own interest, sustainability commitments and environmental awareness. This fact reveals that the independent action of cities have been able to supply partially the lack of effective support from the upper levels of government, and their complete integration in the national climate strategy. The previous experience that cities had developed in the implementation of a relevant

environmental dimension in urban planning has been a relevant factor that has led them to act. Climate action developed by cities in Italy and Spain shows that cities have been sites for environmental policy making and policy innovation, both acting as means to address the environmental challenge (Sassen, 2013). The local proactive action developed by these cities, has helped to improve the overall climate performance of their respective countries.

The “loneliness” of cities regarding climate action in both countries underlines the necessity of coherent multi-level and effective climate frameworks, where cities can make visible their problems and limitations to undertake action in this policy field to the upper tiers of government, and understand the role they have to assume in their respective countries (and regions) to contribute to the achievement of national goals and international commitments. The necessity of greater integration of the policy action developed by the different tiers of government can be extended to other national contexts of the EU based on federal and other decentralized institutional structures. There, as in the cases studied, the potential cities offer to fight and adapt to climate change needs to be fully integrated, through multi-level collaborative approaches, in the national climate policy.

Acknowledgements

This study stems from previous work that addressed the analysis of urban leadership in climate change responses in 11 EU countries (Reckien et al., 2014 and also Reckien et al. this volume). The work developed for the Italian case has been undertaken using as a reference and in complementarity with Salvia et al. (this volume). An extended version of this work has been published in BC3 Working Paper Series: De Gregorio et al (2014) and Olazabal et al (2014). The research team wishes to thank for their contribution providing information to this work to: Laura Crespo, Fernando Jiménez and Carlos López Monllor (CEDEX, Spain); and Ángel Cediél (IDAE, Ministerio de Industria, Energía y Turismo, Spain).

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Box III-3: The Climate Engagement Index (CEI)

Johannes Flacke¹, Diana Reckien

¹ Twente University, E-mail: j.flacke@utwente.nl

In order to assess progress in responding to climate change a question of societal interest and often raised by decision makers is: “Who contributes how much to climate protection”? To answer this question various indicators and scores have been developed e.g. tracking the performance of companies, countries, or cities with respect to their climate change plans and action: The CDP’s Climate Disclosure Leadership Index (CDLI) for instance provides a disclosure score, which assesses the level of detail and comprehensiveness for disclosing the companies’ consideration of business-specific risks and potential opportunities related to climate change, and a performance score, which assesses the level of action taken on climate change evidenced by the company (CDP 2013); the climate change performance index (CCPI) reports annually about the actions of 58 developed countries and countries in transition on reducing carbon emissions (Burck et al. 2013). A comprehensive and aggregated measurement of the climate change activities for cities is still missing, particularly when it comes to reflecting ambitious integrated thinking of cities to address both adaptation and mitigation simultaneously. The only available index (Rifle et al. 2013) is relying on self-reported data and therefore makes it difficult to compare cities objectively.

We present here for the first time such an integrated index showing the overall engagement of cities in terms of climate change based on published plans and activities. The Climate Engagement Index (CEI) is an aggregated score that combines a city’s activities in the fields of local adaptation and mitigation planning with institutional indicators and the citizens’ perception of municipal performance. The CEI is composed of the following 10 indicators:

1. Availability of a local climate change mitigation plan
2. Availability of a local climate change adaptation plan
3. Status of the climate change mitigation plan (in development, draft, approved, published)
4. Status of the climate change adaptation plan (in development, draft, approved, published)
5. Ambitions for planned local CO₂-reductions as stated in the mitigation plan
6. Measures for climate change mitigation defined in the plan
7. Measures for climate change adaptation defined in the plan
8. Integration of local climate change adaptation and mitigation plans
9. Engagement of the city in climate change related networks and associations
10. Level of climate change activities of the municipality as perceived by its citizens

The data for calculating the CEI is taken from the database described by Reckien et al. (2014). For the calculation of the CEI a maximum of 10 points is awarded to each of the indicators listed above depending on the cities’ performance with respect to each indicator. The higher the performance of the city for an indicator, the more points are awarded. For the three dichotomous indicators included in the list (1, 2 and 8) 10 points are awarded if the indicator is true and 0 points if not. In the summation to calculate the overall CEI all indicators are weighted equally.

Results show a wide range of CEI among the 200 cities investigated. Cities with the highest degree of climate engagement achieve a total score of more than 90 points (on a scale between 0 and 100), while 35 % of the cities surveyed score 10 points or below. In total only 32 % of the cities score above 50 points. Among the 65 cities that score above 50 points are 24 UK cities, 16 German cities and 11 French cities. While the UK and Germany are also among the top countries when looking at

national averages (Figure B3.3.1), the results for France reveal large differences between cities as some perform above average but also 20 cities score below 30 points. Also Dutch cities in general show a good performance on the mitigation side but lack actions on the adaptation side; the latter is often addressed by national policies, e.g. in terms of the national flood protection program.

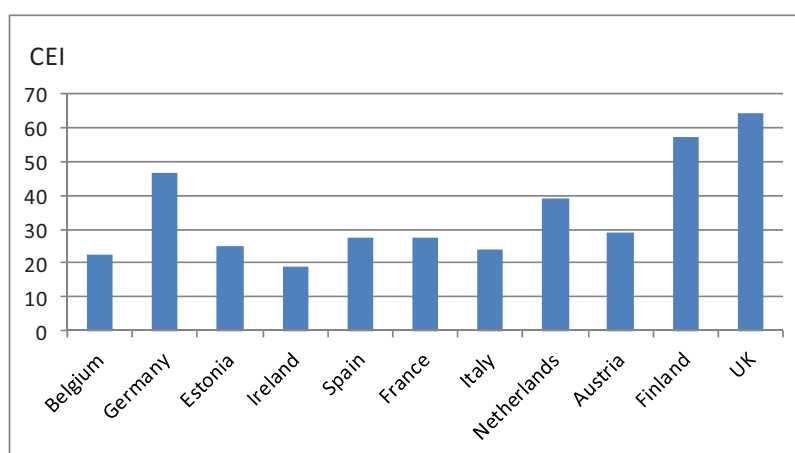


Figure B3.3.1 National averages for CEI based on 200 nationally representative European cities.

Six out of eleven European capital cities investigated are among the 65 cities that score above 50, which shows that some but not all large European capital cities could be seen as climate leaders. However only 2 capital cities are among the top five (Table B3.3.1). Berlin, Bordeaux and Newcastle lead the European activities in terms of overall municipal climate engagement using the CEI index.

Table B3.3.1 Top five scoring cities in terms of overall municipal Climate Engagement Index (CEI).

	CEI score
Berlin (Germany)	96
Bordeaux (France)	95
Newcastle upon Tyne (UK)	93
Essen (Germany)	93
Madrid (Spain)	92

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Photographer: Annemie Wyckmans

Green and blue infrastructures as enablers of resilient cities

Section IV

Green and blue infrastructures as enablers of resilient cities

Annemie Wyckmans¹

¹ *Department of Architectural Design, History and Technology, Faculty of Architecture and Fine Art, Norwegian University of Science and Technology (NTNU), Norway. annemie.wyckmans@ntnu.no.*

This Section examines the role of green and blue infrastructures (GUI) in resilient cities. Green and blue infrastructures are widely credited for providing an attractive visual environment and valuable ecological habitats. Well-adjusted to environmental and social conditions of a city, their social and environmental co-benefits are emphasized, and their presence lauded for improving citizens' quality of life. Thus green and blue infrastructures provide an excellent stimulus for thinking about urban integration.

While the topic is gaining ground in policy and governance processes, the definition and implementation of green and blue infrastructures and assessment of their intended and unintended consequences are highly variable. In this section, Giedych et al., explore the way the term and the idea is understood by urban planners, local authorities, local people and other stakeholders is still not clear and differs from country to country and from specialist to specialist. An examination of the strengths and weaknesses of green and blue infrastructures in policy and governance, based on cases in Poland, United Kingdom, Czech Republic and Turkey shows wide variation in terms of quality, monitoring and documentation, and a large potential for improvement. Sculczewska et al. demonstrate how these variations are partially due to different consequences of climate change in each country, but also different degrees to which the problem has been recognised at the country, regional and local levels of administration.

Tools for design and planning of green and blue infrastructures, such as eco-spatial indices, are available but not commonly used. Gualtieri et al. highlight how it is important to understand and consider all the relationships between the components and agents of the urban metabolism, including the interaction between green, blue and grey infrastructures, and to develop indices and tools that can assess this systemic approach. Indicators and assessment tools are often linked to particular functions only, Demuzere et al. synthesise the evidence of the multi-functionality of green and blue infrastructures in urban areas and to enable decision-makers to fully grasp their potential contribution to climate change adaptation and mitigation efforts in cities.

Section IV-1

Green infrastructure as a tool of urban areas sustainable development

Renata Giedych¹, Barbara Szulczewska¹, Stephen Dobson²,
Lena Halounova³, Hakan Doygun⁴

¹ *Warsaw University of Life Sciences – SGGW, Faculty of Horticulture, Biotechnology and Landscape Architecture, Department of Landscape Architecture, Poland*

² *Sheffield Business School at Sheffield Hallam University, Centre for Individual and Organisational Development*

³ *Czech Technical University in Prague, Faculty of Civil Engineering, Czech Republic*

⁴ *Kahramanmaraş Sutcu Imam University, Faculty of Forestry, Department of Landscape Architecture, Turkey*

Highlights

- Green infrastructure is a complex physical structure forming urban space and performing various functions simultaneously: in biodiversity protection, water management, local climate conditions improvement on one side and as social infrastructure for leisure, relaxation, human interactions on the other.
- Awareness about this multifunctional nature is widely distributed among professionals – urban planners, geographers, landscape architects as well as representatives of cities authorities.
- In all surveyed countries (Poland, Czech Republic, Turkey, United Kingdom) local plans are considered as main instruments of green infrastructure implementation.
- On the basis of legal framework in particular countries and planning documents for analyzed cities we identified that the recognition of functions of potential elements of green infrastructure differ from country to country.
- In general the environmental and recreational functions are emphasized. Less attention is paid to its technical role related to flood control and storm water management.

1 Introduction

The term “Green Infrastructure” began to emerge in the mid-1990s as a means to distinguish between the formal parks and amenity spaces in urban areas and the growing recognition of the value gained from connectivity amongst informal spaces, street trees (McPherson and Peper, 1996), walkways, and incidental urban greening. The concept was not new as Walmsley (1995) reminds us that connectivity between greenways, greenbelts and green spaces were a key component of Howard's vision of town and country. However, the term green “infrastructure”, attributed to a Florida governor in 1994, subsequently gained popularity since it perhaps captures a more coordinated and architecturally resonant vision of actions as well as wider variety of urban typologies. Van der Valk and Faludi (1997) evaluate the status of the “Green Heart” concept from

the Netherlands and associated pressures from population increase and housing need and define a necessity to invest in both green and blue “infrastructures”.

The concept of green infrastructure is now considered as one of the key ideas of sustainable development at regional and local scale. The way the term and the idea is understood by urban planners, local authorities, local people and other stakeholders is still not clear and differs from country to country and from specialist to specialist.

Based on a review of definitions, Sylwester (2009) distinguishes different meanings of green infrastructure. It could be understood as region's life support system; strategically planned and managed networks of natural areas; physical environment within and between our cities, towns and villages; network of multi-functional open spaces; management approaches and technologies; or strategic approach to land conservation.

Nevertheless, because of its potential, importance and crucial role in shaping urban environment by providing ecological services and being a place for everyday recreation it is worth to be transformed into broadly used instrument of urban planning and strategic approach to land conservation which combines land conservation and land use planning (Ahern, 2010, Hostler et al. 2011, Madueira et al. 2011, Sandström, 2009)

The aim of the paper is to examine the state of green infrastructure idea implementation in different planning regimes and governance levels. Four cities: Warsaw (Poland), Gaziantep (Turkey) , Hradec Kralove (Czech Republic) and Sheffield (United Kingdom) were chosen as case studies.

2 Materials and methods

Our research was based on information concerning recognition, planning, protection and maintenance of green infrastructure or areas that could be considered as GI elements (green spaces) as in certain countries GI concept is not implemented yet. The following materials were studied:

- Scientific papers published in surveyed countries which introduces green infrastructure concept and describes its meaning for sustainable development of cities (we considered only tis publications where the term “green infrastructure” was used) ;
- Legal acts on spatial planning, environmental and nature protection, and others which regulate development and management of green infrastructure or green spaces; and,
- Planning documents for surveyed cities (e.g. spatial plans, environmental protection programs, landscape plans, development strategies, etc.) being in force at the moment.

We formulated the following questions to understand how far we are from green infrastructure concept implementation and what can be considered as a common approach:

- Are the term and concept of GI present in scientific publications, legal acts, official governmental documents?
- How is green infrastructure or its potential elements presented in spatial planning documents on the city level (elements and provisions)?
- What sorts of organizations are responsible for green infrastructure elements construction and maintenance?

3 Recognition of green infrastructure as a concept

The green infrastructure concept is not very well recognized in Poland, Czech Republic and Turkey. In the United Kingdom on the other hand it is widely acknowledged as an important part of city planning.

In UK practice, some of the earlier reports to adopt the term 'Green Infrastructure' include the East Midlands Green Infrastructure Scoping Study (TEP, IBIS, 2005) and the Green Infrastructure Guide for Milton Keynes and the South Midlands (Environment Agency et al., 2005). Kambites and Owen's (2006) review of practice suggests that it is the guides created by the Environment Agency et al (2005) and the Landscape Partnership (2005) which had been influential in subsequent local authority uptake nationally. However, the term has remained relatively misunderstood in practice until surprisingly recently.

In 2009 when the Landscape Institute first launched its Position Statement on green infrastructure (GI), the concept of GI was not commonly understood, and had relatively little public status. In the four short years since then the collective knowledge and understanding has grown exponentially, and the concept has become pervasive at all levels of government, throughout the private sector, and with the public. It is now endorsed and promoted at all levels by a wide range of organisations, each promoting its benefits from their own perspective (LI, 2013).

According to Mell (2008) not only the practical application but also conceptual research of Davies et al. (2006) and Gill et al. (2007) has been at the forefront of the green infrastructure idea implementation in UK.

In Poland only a few publications that relate to the concept of green infrastructure, especially the green infrastructure of the city were found. These publications relate to issues on the principles of green infrastructure planning, its functions and structure (e.g. Szulczewska, 2006, 2009; Kowalski, 2010; Jeleński, 2010). Among these works special attention is due the analysis of Szulczewska (2006), which presents the possibility of adapting the concept of green infrastructure planning as an instrument of Polish cities. Recent studies of Giedych et. al. (2012) show the problems of green infrastructure management at the city level.

There are only a few publications about green infrastructure in the Czech Republic. Most of them are results or reports of European projects (e.g., CEEweb for Biodiversity, 2011). In 2012 a special issue of The Nature Conservation Journal (Ochrana Přírody) introduced the concept of green infrastructure (e.g., Plesnik, 2012; Miko, 2012) and its application in Czech conditions (e.g., Hátle, 2012). Besides the term green infrastructure in Czech Republic also the term ecological infrastructure is used (Plesnik and Vitek, 2012) along with biological infrastructure (Pešout and Hošek, 2012). Issues related to urban green infrastructure were discussed by Šerá (2013).

In Turkey there are practically no publications on green infrastructure in the national language. However, articles on green infrastructure of Turkish authors in English can be found (e.g., Kaplan 2010, 2012).

4 Legal base for green infrastructure creation and protection

The term and entire concept of green infrastructure is officially recognized only in the United Kingdom. In other surveyed countries the legal base for green infrastructure development refers

mostly to acts of law related to green areas planning, nature conservation and environment protection.

These acts define categories of green spaces, their functions and instruments of implementation. In general the regulations emphasize the environmental and recreational functions of green spaces. Less attention is paid to their technical role related to flood control and storm water management. In all countries the city spatial planning documents are the basic tools for creation and protection of the green spaces (Table 4.1.1).

Local Development Frameworks (LDF) – introduced in England and Wales through the Planning and Compulsory Purchase Act 2004 – establish spatial planning policy for all area development and regeneration at the local level. LDF provide the opportunity to co-ordinate city-wide planning and design of green infrastructure. Each local authority's LDF was designed to sit within a broader Regional Spatial Strategy (RSS) which was considered as providing a regional and sub-regional context for green infrastructure. The RSS was recently abolished as part of a new UK 'Localism Bill' emphasising community-led planning involvement but has resulted in government lobbying from national environment groups to re-address the policy mechanisms for 'larger-than-local-planning'. Currently, specific policy statements and guidance concerning green infrastructure in England are:

PPS1: Delivering Sustainable Development. This statement sets out the Government's overarching planning policies on the delivery of sustainable development through the planning system. It includes the requirement to optimize potential for green and other public space throughout development.

PPS9: Biodiversity and Geological Conservation. Published in 2006 this statement sets out planning policies on protection of biodiversity and geological conservation through the planning system. It states that:

“Networks of natural habitats provide a valuable resource. They can link sites of biodiversity importance and provide routes or stepping stones for the migration, dispersal and genetic exchange of species in the wider environment. Local authorities should aim to maintain networks by avoiding or repairing the fragmentation and isolation of natural habitats through policies in plans. Such networks should be protected from development, and, where possible, strengthened by or integrated within it. This may be done as part of a wider strategy for the protection and extension of open space and access routes such as canals and rivers, including those within urban areas.” (PPS 9)

PPS 12: Local Spatial Planning. This statement requires local authorities to include statements about the provision for local green infrastructure within their core strategy.

PPG17: open space, sport and recreation. Originally published in 1991 and updated in 2002, it provided key guidance to authorities on producing coordinated green and open space strategies which encourage full functionality of green infrastructure.

PPS25: development and flood risk. This statement was first published in 2001 and then refreshed in 2005 and highlights the role of green infrastructure in supporting sustainable drainage and mitigating flood risk.

Table 4.1.1 Legal base for green spaces identification, protection, functions and planning.

Country	Green spaces identification	Green spaces protection	Green spaces functions	Green spaces planning
POLAND	Nature conservation act (2004)	Nature conservation act (2004)	Nature conservation act (2004)	Ordinance on the required scope of the local plans (2003)
	Defines functions and categories of green open spaces	Green open spaces are one of nature protection categories	Nature conservation environment performance recreation	Green urban spaces are elements of planning documents Environmental protection act (2001) Requirement of establishment minimal size of biologically vital area (covered with vegetation and/or water) in relation to the plot size
TURKEY	Construction law (1985)	-	Ordinance on the fundamentals for performing plan (1985)	Ordinance on the fundamentals for performing plan (1985)
	Defines the limitations and the forms of use of public open and green areas	-	Recreation	Defines the green area types and minimal standard of urban green spaces per capita
CZECH REPUBLIC	Law of city planning and civil engineering regulation (1976)	Nature and landscape protection act (1992)	Law of city planning and civil engineering regulation (1976)	Law of city planning and civil engineering regulation (1976)
	Defines categories of green spaces	Requirement of creation landscape system of ecological stability	Recreation Nature and landscape protection act (1992) Environment performance	Green urban spaces are elements of planning documents
UNITED KINGDOM	PPG 17: Planning for open space, sport and recreation (2002)	PPS 9: Biodiversity and geological conservation (2006)	PPS 25: Development of flood risk (2010)	PPS 12: Local spatial planning (2008)
	Defines functions and categories of green open spaces	Recognizes green infrastructure as crucial for biodiversity conservation	Flood risk mitigation sustainable drainage	Provisions for local green infrastructure in planning documents
			PPG 17: Planning for open space, sport and recreation (2002)	PPS 1: Delivering sustainable development (2005)
			Recreation PPS 9: Biodiversity and geological conservation (2006) Biodiversity conservation	Requirement to optimize potential for green spaces development PPS 25: Development of flood risk (2010) Green infrastructure is crucial for supporting sustainable drainage and mitigating flood risk

Additionally, the *Natural Environment and Rural Communities (NERC) Act*, which came into force 1st October 2006, contains a 'duty to conserve biodiversity' (Section 40) and a requirement that the Secretary of State must publish a biodiversity and action list for the conservation of 'important living organisms and habitats' (Sections 41: England, Section 42: Wales). However the correlation between habitats and green infrastructure is not explicitly underlined in this document.

In Czech Republic the first law dealing with greenery was approved in 1976 and was embedded in the Law of City Planning and Civil Engineering regulations No. 50/1876. Further development of the legal base was enlarged by the Law No. 114/1992 about the nature and landscape protection referring other green features. The Rainbow program was an important step in the green infrastructure control and planning. The greenery systems of USES should respect different scales and set up a renovation of ecological balance. The process of further improvement of the legal base was implemented in the Law of Landscape Planning and Civil Engineering regulations No. 183 from 2006. Methodologically unified approach is ensured by analytical landscape base documents being a source for city plans for the landscape sustainable development. The city plans are the basic tool for protection and creation of the green infrastructure.

Three acts of law could be considered as relevant for protection and development of green infrastructure in Poland: Nature Conservation Act (2004), Environmental Protection Law (2001) and Spatial Planning and Spatial Management Act (2003).

The Nature Conservation Act defines green open spaces. In accordance with the findings of the Act green areas are understood as: areas covered with vegetation with technical infrastructure and buildings functionally associated with them, performing the functions of aesthetic, recreational, health or buffering, in particular: parks, green squares, promenades, botanical gardens, zoological gardens, historical gardens; as well as the greenery accompanying streets, squares, fortifications, buildings, storage sites, airports, railway trails, and industrial constructions.

Under the regulations of The Environmental Protection Law Polish planners become equipped with sort of integrative approach instrument for green spaces planning: they are entitled to establish proportion between built-up and biologically vital areas (green areas) necessary for preservation of a balance with nature on the site. According to the Spatial Planning and Spatial Management Act, establishment of the ratio of biologically vital areas is one of the basic provisions of the planning documents at a local level.

In Turkey under regulations of Environmental Law enacted in 1983, urban master plans and urban development plans are carried out in accordance with environmental development plans (which are prepared at the regional and watershed scales). Urban green spaces are accounted for in master and development plans; however, there exists no ecological planning approach in the current physical planning system. The only legally binding regulation for urban green areas is the one passed in 1985 requiring 10 m² urban green area per capita.

5 Green infrastructure in surveyed cities

5.1 Types of green spaces, greenery, water bodies considered as an element of green infrastructure

5.1.1 Warsaw, Poland

As potential elements of green infrastructure in Warsaw in the first order can be regarded: green spaces (parks, didactic gardens, allotment gardens, and cemeteries), open water, forests and remainders of agricultural areas. But the urban fabric consists also of built-up areas (mostly residential) with a big share of vegetation (biologically vital areas). These areas are particularly important to preserve the continuity of the green infrastructure network. In Warsaw it is not unusual that the ratio of biologically vital areas in housing estates reaches even 50%. The share of greenery accompanying housing estates in the total area of green areas in Warsaw is 16%, while parks and green squares is only 10%. In addition to residential areas the greenery accompanying streets and railway trails may also play an important role in formulation the green infrastructure. The greenery accompanying street areas covers 1078,2 ha which is 9% of the total area of green areas in Warsaw.

5.1.2 Gaziantep, Turkey

Main open and green spaces in the city of Gaziantep are of such types as woodlands, parks, playgrounds, water bodies, wide boulevards with sideline trees, and other barelands. These areas have a great potential to serve as a green infrastructure at the urban scale. In addition, residential gardens may contribute as an important green infrastructure element. The biggest share of contribution to green open spaces of Gaziantep belongs to woodlands and agriculture (40%), with green spaces including graveyards and parks (15%), and Sacir creek and its surroundings (5%).

Sacir creek and its surroundings including agricultural and green areas are the most powerful avenue to form the green infrastructure of Gaziantep. Urban green spaces exhibit a scattered and sparse structure which is the weakest facet of Gaziantep's current state.

5.1.3 Hradec Kralove, Czech Republic

The main green spaces in Hradec Králové which may create the green infrastructure are as follows: parks and forest parks, recreational forests, agronomical forests, private gardens, plantations and orchards, cemeteries, small green areas, golf areas and water courses. Urban greenery covers 353 ha in 2009 while forests cover 2570 ha in the same year.

Elbe and Orlice rivers can be considered as the backbone for establishing a green infrastructure corridor in the city. The forests which surround the city in the east, and agricultural areas around the city can also be used as potential to support vital effectiveness of the green system.

5.1.4 Sheffield, United Kingdom

The city is described as combining a wide variety of habitats, including: urban, suburban, parkland and woodland (including some remnant ancient woodland), agricultural land, meadow and freshwater. With an estimated total of over two million trees, Sheffield has more trees per person than any other city in Europe (SCC 2007a). *"It has over 170 woodlands, 78 public parks and 10 public gardens. Added to this are 135 km² of national park and almost 11 km² of water."* (SCC, 2007a).

When compared to many other European cities, Sheffield considers itself to have: “... *more public parks and green spaces, more tree cover, and also boasts the Peak National Park within its city boundary. This unique combination already makes Sheffield the greenest city in Britain*” (SCC, 2007b).

5.2 Planning of green areas

5.2.1 Warsaw, Poland

The most important instrument of sustainable development at the local level is *The Study of the Preconditions and Directions for the Community Spatial Development*. The *Study* is prepared in concordance with Spatial Development and Planning Act (2003). It is a comprehensive plan of future development, which defines: directions of changes in the spatial structure of a city and in the land use, parameters related to the development (e.g., ratio of biologically vital areas, floor area ratio, and height of buildings), directions and rules of natural and cultural heritage protection, transport systems and technical infrastructure development. The *Study* is a document of analytical, informative and coordinating nature.

The *Study for Warsaw*, which at the moment is in force, was adopted in 2006. The main provisions of the *Study* related to the topic are: green urban spaces, nature conservation system and urban natural system.

Urban green areas are regarded as some of the main elements of natural heritage of the city. The *nature conservation system* shows areas that are under formal protection. Nature conservation brings limitation in land use changes and restrictions in future development.

The *Urban Natural System* includes areas that are particularly important for environmental performance of the city. *Primary areas* of the system are generally excluded from the construction. In *supporting areas* (that may be dedicated for future development) the minimal size of biologically vital areas is defined.

5.2.2 Gaziantep, Turkey

Two planning documents, worked out at the regional and local level, include provisions related to green spaces planning. The Environmental Development Plan, based on Environmental Law (1983) is elaborated at the regional and watershed scales (with resolutions of 1:100.000 to 1: 25.000). The Urban Master Development Plan (with resolutions of 1:5000 to 1:1000), and Urban Implementary Development Plan (with resolution of 1:1000) are carried out in accordance with environmental development plans, respectively.

The Urban Master Development Plan for Gaziantep, adopted in the 2000s, regulates main land use types such as: residential, industrial, and green areas, main transport arteries, and population densities. The Urban Implementary Development Plan gives detailed information by both map and text report form. That 1:1000 scale map gives areal information on floor area ratio, height of buildings etc while the report explains the reasons and the formulas which used to reach areal decisions on the map. These types of plans are prepared in concordance with the Construction Law (3194/1985). The Urban Implementary Development Plan map gives the exact locations and the types of green areas. This plan is prepared considering future population scenarios which were calculated using projection methods. And, it is obligatory that all *urban implementary development*

plans should contain a minimum amount of urban green area which is needed for the projected future population.

Gaziantep municipality has put into force its own construction regulation in 2008. This regulation classifies all types of green and recreation areas, and gives detailed rules of their use and construction at local scale. This regulation is of great importance due to the green band concept that recommends connectivity of green areas. This could be considered as a green infrastructure approach.

5.2.3 Hradec Kralove, Czech Republic

There are two levels of city planning in the Czech Republic. The upper level is called *Fundamentals of the landscape development*. They determine main directions, conditions and priorities for whole regions, and thus for the Hradec Králové Region development. The *Fundamentals* were processed by the Landscape Planning Department of the Hradec Králové Region Authority according to the new Building Act published in 2006. The *Fundamentals* propose limits of the regionally important developing areas, traffic and technical infrastructure, landscape system of ecological stability and civil engineering projects of high public importance. The *Fundamentals* must be approved by the Region Council.

City plans are the lower level of the spatial planning. They have two parts of the documentation - a text and map ones. The Binding Part of the Plan is the text document determining what land use types and objects are allowed to occur in individual city plan classes (legend). The city plan in the form of a map document is the second part. The Binding Part of the Plan is prepared in concordance with the Law on Spatial Planning and Building Regulations (N° 50/1976) and the Ordinance on the Spatial Planning Fundamentals and Spatial Planning Documentation (N° 135/2001).

The *Spatial Analytical Basic Documents* processed by the Regional Authority as the methodological tool for the unified approach and protection of the greenery were updated in December 2010.

The present city plan was approved in 2000. It should be adapted according to comments/demands of inhabitants again respecting the Binding Part that is finally approved by the city council. The green areas form individual classes with limits for other land use types in their locations on one hand, and are regarded and regulated also in other land use classes, even the industrial one, e.g., on the other hand.

The goal of all of these documents is to continue in the main direction and that is the sustainable development of cities as a whole; however, green areas are substantially protected.

5.2.4 Sheffield, United Kingdom

To help maintain and enhance the city's green infrastructure the local authority has developed the Sheffield Green and Open Space Strategy (SGOSS) which sets out both a vision and proposals for achieving this vision over the next 20 years. These are underpinned by the strategic themes: People, Places, Environment & Sustainability, and Quality Management.

The scope of the SGOSS encompasses all green and open spaces within the metropolitan area and therefore has a very integrating emphasis. The metropolitan area incorporates both urban and rural aspects of Sheffield including the Peak National Park. Planning is therefore coordinated through two responsible authorities, Sheffield City Council and the Peak District National Park Authority.

The authorities develop Local Development Frameworks, as part of national planning requirements, within which a Core Strategy document is produced to set out the strategic spatial vision.

Sheffield City Council considers the SGOSS to be an ambitious strategy particularly since it covers all green and open spaces and therefore is across all ownership. The Sheffield City Council ‘Culture, Economy and Sustainability Scrutiny Committee Report’ released on 2nd November 2010 (SCC 2010a) underlines both this ambition and the need for local Community Assemblies (community-focused governance entities) to adopt priorities from the SGOSS within their own local plans. In this sense the complex multi-layered, multi-stakeholder nature of integrated approaches to green infrastructure planning in practice are evident. This report states that the assemblies must outline their priority sites for ‘quality uplift’ within a local plan, along with ‘an achievable programme of improvements to raise standards’. The championing of green infrastructure in order to deliver the SGOSS is underlined in that: *“Local area ownership and stakeholder buy-in will be essential if the strategy is to be realised”*. (SCC 2010a)

The overarching Sheffield Development Framework (SDF) refers to the tension between ‘certainty and flexibility’ within its planning framework – both of which it suggests are important for regeneration and growth and particularly relevant when considering green infrastructure as incorporating many land owners and community planning ‘voices’:

“...the greater the certainty given by a policy the less the flexibility it allows and the more flexibility that is built in the less certain users can be about the outcome... The overall approach in the SDF is to create certainty through allocating specific sites for particular uses and to enable flexibility through designation of wider policy areas, where certain uses are preferred but a range of others is still acceptable.” (SCC, 2010b)

5.3 Green infrastructure management

5.3.1 Warsaw, Poland

Management of green structure in Warsaw is dispersed among a dozen parties. The responsibility is closely related to the ownership structure. Of the total number of 84 parks in Warsaw, 68 are managed by the Warsaw Municipality. Iconic, historical parks are managed by the Ministry of Culture and National Heritage, botanical gardens by scientific institutions (Polish Academy of Science and University of Warsaw). It must be stressed that 68 parks managed by City of Warsaw are maintained by different Municipal Units – Environmental Protection Departments of 17 Warsaw’s Districts, Public Space Management Authority and Municipal Clearing Administration. Other potential elements of green infrastructure are managed by:

- Regional Water Management Authority: Vistula river corridor with adjacent riparian zone, Zegrzyński Watercourse, Służewski Brook;
- Municipal Forest Authority, Regional Directorate of State Forests: forests;
- Municipal Cemeteries: Masovian Voivodship, Churches and congregations: cemeteries;
- Polish Allotment Gardens Society: allotment gardens;
- Municipality of Warsaw, Polish National Railways: greenery accompanying streets and railway trails;
- Municipality of Warsaw, legal and natural persons: greenery accompanying housing estates;
- Legal and natural persons: agricultural land;

- Regional Directorate of Environment Protection: nature reserves and other nature protection areas.

This complicated ownership structure could be one of the obstacles to implement the idea of green infrastructure.

5.3.2 Gaziantep, Turkey

Parks in the city of Gaziantep are managed by three municipal bodies. The same applies to urban transportation, forestry, and Sacir creek management. The potential elements of green infrastructure are owned by private and public bodies. This causes obstacles for designing and compounding the open and green areas systematically.

5.3.3 Hradec Kralove, Czech Republic

The responsibility for management of green spaces, as in Poland, is divided into many parties. It relates to ownership structure. The Hradec Králové Municipality is owner and manager of cemeteries, parks, forest parks, and recreational forests. Agronomical forests are either owned by state and managed by the Forests of the Czech Republic as a state organization, or by private owners.

5.3.4 Sheffield, United Kingdom

Green space management based upon collaboration between multiple partners with: “*jointly agreed principles, values, objectives and priorities*” are acknowledged as a necessary management approach to adopt (DLTR, 2002) for delivering green infrastructure. Key actions around quality management within a multi-partner approach, incorporating community residents, local business, and other interested parties, are:

- QM Q1 Develop benchmarked Sheffield Quality Standards, relevant to different types of green and open space, their users and their management.
 - Developing a quality standard that defines the baseline expectations for public green and open spaces, by 2010.
 - Developing a full quality standard of management for the wider benefits of green and open spaces by 2012.
- QM Q2 Adopt local quality indicators and respective targets to drive quality improvement at area, city and national levels.
 - Developing a quality standard that defines the baseline expectations for public green and open spaces, by 2010.
 - Develop targets and progressively improve key sites in each area to the full quality standard by 2024.
- QM Q3 Implement and maintain quality improvement through management planning for each green and open space.
 - Develop a common management plan framework to support planning across site types and managers by 2012.
 - Update the business case for on-going site management to meet and maintain the Sheffield Quality Standard by 2012.
 - Complete management plans for all sites/ types, by 2020 (SCC, 2010c).

6 Discussion and conclusions

Benedict and McMahon (2006) define green infrastructure as a network of natural areas and other open space that conserves natural ecosystem values and functions, sustain clean air and water, and provide a wide array of benefits to people and wildlife. This definition emphasizes the complexity of green infrastructure, which could be described as a physical structure forming the city space that at the same time plays different roles: in biodiversity protection, water management, local climate conditions improvement on one side and as social infrastructure for leisure, relaxation, human interactions on the other.

Despite the fact that the green infrastructure concept is in its infancy stage in Poland and Czech Republic it doesn't mean that green spaces are not developed and maintained in those countries. Also awareness about their multifunctional nature is widely distributed among professionals – urban planners, geographers, landscape architects as well as representatives of cities authorities.

It is worth to mention that Territorial Systems of Ecological Stability (TSES) at supraregional, regional and local level was developed in the Czech Republic in 1970-ies. This concept is now considered as one of the best operative green infrastructure network in Europe (CEEweb for Biodiversity, 2011).

In Polish planning and nature conservation practice there were developed similar concepts which underpin a green infrastructure approach, such as multi-functionality and connectivity. They were worked out in 1980-ies and for local level published a bit later: Urban Natural System (Szulczewska and Kaftan, 1996), and Ecological Framework (Przewoźniak, 2002).

The difference between those concepts and the green infrastructure idea consists in the main, general focus: green infrastructure must be created as a multifunctional structure while the mentioned concepts concentrated only on ecological issues. Other issues such as social or aesthetical were left behind on the basis of assumption that they require different criteria and should be considered as the next “layers”. But in both discussed approaches connectivity was adopted as a key principle of planning and development.

As green infrastructure measure can be also regarded Ratio of Biologically Vital Area (RBVA) which is used in Polish planning practice since mid-1990s. RBVA expressed the ratio between areas covered by vegetation or open water (not sealed areas) to the plot size. Similar solutions (see Box 1), which main aim is to sustain natural processes, are also applied in Berlin, Malmo, Seattle and Singapore (Szulczewska et al., 2014).

The only official work towards “green infrastructure” approach established in Turkey is the integrated urban development strategy and action plan realized in 2010 under the coordination of the Ministry of Public Buildings and Works which is not legally binding for the present (IUDSAP, 2010).

The concept of green infrastructure is already implemented only in United Kingdom. In other surveyed countries there is a big potential of its implementation in terms of theoretical basis (e.g. Urban Natural System (Poland), Territorial System Of Ecological Stability (Czech Republic)) as well as legal basis. In surveyed countries there are no regulations dedicated only to green infrastructure. As relevant for the creation and protection of green infrastructure could be regarded

general acts of law related to land use planning. In all surveyed countries local plans are considered as main instruments of green infrastructure implementation.

In all surveyed cities the areas most frequently identified as the existing or potential elements of green infrastructure were as follows: parks, forests, water bodies, agricultural areas. The greenery accompanying roads, railway lines and housing estates were also considered as potential elements of green infrastructure. This indicates that regardless of natural conditions, the most important elements of green infrastructure are almost the same.

On the basis of legal framework in particular countries and planning documents for analyzed cities we identified that the recognition of functions of potential elements of green infrastructure differ from country to country. In general the environmental and recreational functions are emphasized. Less attention is paid to its technical role related to flood control and storm water management.

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Box IV-1: Eco-spatial indices - green infrastructure site scale solutions

Renata Giedych¹

¹ *Warsaw University of Life Sciences – SGGW, Faculty of Horticulture, Biotechnology and Landscape Architecture, Department of Landscape Architecture, Poland. Email: renata_giedych@sggw.pl*

Eco-spatial indices are planning and design tools designed to keep balance between built up and green areas (Szulczewska et al., 2014).

Eco-spatial indices are expressed as the ratio between different “ecologically friendly” elements on site. They are applied in built up areas. Individual elements of land cover are weighted from 0.0 (impermeable surfaces) to 1.0 (surfaces covered by vegetation on the ground, open water) per square meter. Each development should achieve a minimum index value. Developers can choose different elements from the “green menu”, e.g. areas covered by vegetation, open water, different plant features (e.g., height, type of canopy, trunk diameter), bioretention facilities, permeable surfaces.

Table B4.1.1 shows comparison of five eco-spatial indices applied in different planning regimes:

- **BAF** - Biotope Area Factor (introduced in Berlin in 1994)
- **GF** - Green Factor (introduced in Malmo in 2001)
- **RBVA** - Ratio of Biologically Vital Areas (introduced in Poland in 2002)
- **GnP** - Greenery Provision (introduced in Singapore in 2005)
- **SGF** - Seattle Green Factor (introduced in Seattle in 2007)

Table B4.1.1 Key features differentiating the ecological value of the site.

Eco-friendly elements	BAF	GF	RBVA	GnP	SGF
Areas covered by vegetation	■	■	■	■	■
Green roofs	■	■	■	■	■
Vertical greenery	■	■		■	■
Different plant features		■		■	■
Permeable paving	■	■			■
Open water	■	■	■		■
Bioretention facilities	■	■			■

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Section IV-2

Planning measures for ecosystem-based adaptation capacity of cities: a comparative study

Barbara Szulczewska¹, Renata Giedych¹, Stephen Dobson², Hakan Doygun³,
Lena Halounova⁴, Engin Nurlu⁵ and Adam Pirowski¹

¹ *Warsaw University of Life Sciences – SGGW, Department of Landscape Architecture, Poland*

² *Sheffield Business School, Sheffield Hallam University, United Kingdom*

³ *Kahramanmaras Sutcu Imam University, Faculty of Forestry, Department of Landscape Architecture, Turkey*

⁴ *Czech Technical University in Prague, Faculty of Civil Engineering, Czech Republic*

⁵ *Ege University, Faculty of Agriculture, Department of Landscape Architecture, Turkey*

Highlights

- In all surveyed countries (Poland, Czech Republic, United Kingdom, Turkey) the problem of climate change consequences for nature, economy and society has been recognized. Governments seem to be well aware about climate protection needs, implementation of climate change mitigation and adaptation measures included.
- With the exception of the United Kingdom, legal acts which are in force at the moment and regulate such matters as nature, landscape and environmental (water, air and climate included) protection do not fully acknowledge the problem. The main goals of green spaces protection and development often refer first of all to independent social and ecological needs in the surveyed cities.
- With the exception of Sheffield, suggested measures seem to be based rather on general academic knowledge than on an individual climate change risks assessment in surveyed cities. In depth analysis of projected problems and an evaluation of existing green spaces from the adaptation capacity to climate change point of view would be recommended.

1 Introduction

After reviewing the concept of adaptation of human communities to global changes, especially climate change, Smit & Wandel (2006) come to the conclusion that adaptation is still a novel concept in the climate change field. They also point out that some success in practical implementation of the concept could be found when measures that address climate change risks were incorporated into – among others – land use planning.

In recent decades, spatial planning, land use planning and development planning have been considered crucial for the protection of the environment and the human living conditions on which it depends. To this end, an ecosystem based approach to enhancing adaptation capacity of cities to climate change therefore depends largely on nature (Smit & Wandel, 2006; Vincent, 2007; Engel & Lemos, 2010). In urban areas a natural environment is maintained by green (and blue) spaces. In

recent years many different planning concepts to conserve and enhance green spaces in cities have been applied, namely; ecological networks (Jongman et al., 2004; Opdam, 2005; Bryant, 2006; Ignatieva et al., 2011), ecological land use complementation (Colding, 2007; Jones et al., 2007; Goddard et al., 2010), conservation subdivision (Arendt, 2004; Carter, 2009; Freeman & Bell, 2011), ecosystem services (Bolund & Hunhammar, 1999; Niemelä et al., 2011; Yaella et al., 2012), low impact development (Dietz, 2007; Pyke, 2011) and green infrastructure (Benedict & McMahon, 2006; Hostler et al., 2011). The above mentioned concepts could be considered in terms adaptation capacity, as the green spaces have a beneficial effect on the city by reducing urban heat island, reducing air pollution and noise, supporting sustainable storm water management, and the prevention of flood risk.

Observed climate change, present-day climate variability and future expectations of change are altering the course of development strategies with development agencies and governments now planning for this adaptation challenge (Adger et al., 2003). On the other hand, it is acknowledged that climate change is a global phenomenon that impacts societies throughout different scales - from individuals to localities and entire regions (Laukkonen et al., 2009). Depending on this, regulations and policies developed by authorities and/or governments are wide ranging - from the viewpoints of their awareness on the issue in national and international scale, data flow in a horizontal and vertical manner, and also the level of anticipated or planned negative effects of climate change.

Although the concept of adaptation capacity is not yet broadly adopted in many countries, past practice shows that green space planning has a significant potential to support it.

In this paper we would like to present and compare different ecosystem based measures that refer to adaptation of cities to climate change as applied in development or/and spatial planning in Poland, Czech Republic, United Kingdom, and Turkey. On the basis of this comparison we would like to explore to what extent a common approach may be recommended for cities or alternatively what barriers might exist to prevent this. To begin with we assume that there may be two main reasons for diverse approach; 1) the different consequences of climate change in particular countries; and, 2) the level of problem recognition on country, regional and local level of administration.

2 An ecosystem based adaptation capacity – state of the art

Ecosystem-based adaptation (EbA) is the use of biodiversity and ecosystem services to help people to adapt to the adverse effects of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. EbA can generate significant social, economic and cultural co-benefits, contribute to the conservation of biodiversity, and build on the traditional knowledge and practices of indigenous peoples and local communities.

In cities the scope of adaptation activities is more limited than in rural areas. However, in their implementation not only people but also vulnerability of urban structures and systems (infrastructure) have to be taken into consideration.

In the EEA Report (2012), entitled *Urban adaptation to climate change in Europe, challenges and opportunities for cities, together with supportive national and European policies*, three main challenges to cope with in urban areas were identified: heat, flooding and water scarcity and droughts.

From the paper which results of the GRaBS (*Green and Blue Space Adaptation for Urban Areas and Eco Towns*) project (Hudekova, 2012), the following activities have been recommended as relevant for adaptation capacity building:

1. Alleviating summer heat through:

- Enabling better air circulation throughout the day and night through urban design and the interrelationships between vegetation and buildings;
- Increasing the amount of vegetation, especially in the built-up areas of urban centers (through planting trees along streets and in car parks, creating green dividing strips, and using alternative types of vegetation such as green roofs and climbing and vertical vegetation);
- Increasing the percentage cover of trees and woody plants to more than 60% (compared with lawns) if the infrastructure allows; and,
- Preparing for changes in altitudinal vegetation zones due to increases in temperature – this will affect the water, and provides shielding and protection against erosion.

2. Managing water resources through:

- Protection of vegetation on the banks of waterways; and,
- Increasing the capacity of a water course to improve water quality, using vegetation that provides protection against sedimentation and overgrowth due to the shielding of the riverbed;

3. Reducing flood risk through:

- Introducing an ‘index of maximal impermeableness’ for particular surfaces according to their function (for example, parks and green spaces should not have underground structures such as car parks) in order to increase an area’s retention capacity;
- Setting up systems to collect rainwater from roofs and terraces and distribute it to infiltration and collection polders or gardens – this would help to reduce the desiccation of the urban landscape and drain rainwater (on public municipal spaces permeable surfaces should be retained);
- Increasing vegetation using a range of green spaces, such as green roofs, climbing species, vertical gardens, and so on;
- Implementing measures to protect against local floods after heavy rain in the hinterland of a municipality – for example, in forest areas such measures could include longer rotation periods, banning clear felling, afforestation, and building polders; and,
- Supporting planting balks, tufts and wind breakers on agricultural land surrounding urban areas.

Taking into account the above recommendations one can find particular importance of areas covered by vegetation in cities for their climate change adaptation capacity building. Those areas should be protected and developed when possible particularly in densely built-up areas. Moreover they should be planned and /or modernized in a way which ensures their role in capacity building. In this context urban green infrastructure concept should be raised. This concept has emerged as arguably one of the most popular climate change adaptation and mitigation measure being discussed (Gill et al., 2007; Naumann et al., 2011).

3 Material and methods

The main body of our research was based on an analysis of planning documents from the point of view of the provisions introducing or / and enhancing adaptation of cities (city spaces) to climate

change. Due to variance in recognition of the problem across the surveyed countries, we decided to precede planning documents comparison by analysis of national policies and strategic documents on which these documents were based. From this it was possible to establish how the problem of climate change was being recognized in a particular country. Most measures could not be implemented without adequate legal regulation. So, we also took into consideration binding legal acts relevant for implementation of surveyed measures. The essential comparisons of planning documents include comprehensive plans (spatial policies), strategies, environmental policies for the following cities: Warsaw (Poland), Prague (Czech Republic), Sheffield (United Kingdom), Gaziantep and Izmir (Turkey) (Table 4.2.1).

Table 4.2.1 Land use in the five surveyed cities. *Sheffield also has 27.9% open land.

City	Population	Urban area (km ²)	Total green space (km ²)	Urban green spaces			Open water (%)
				Formal green spaces (%)	Forest (%)	Agricultural land (%)	
Prague (Czech Republic)	1,242,000	496	195	4	13	20	2
Sheffield * (United Kingdom)	551,800	367	224	8.8	8.6	22.3	1.5
Warsaw (Poland)	1,716,855	517	243	6.46	35.9	50.68	6.96
Izmir (Turkey)	2,781,485	788	288	1.3	25.3	9.9	0.2
Gaziantep (Turkey)	1,400,000	370	73	3	20	50	0.5

On the basis of Hudekova (2012) recommendations, we assumed that the following scope of provisions should be identify and compare:

- The general aims and scope of green space (green infrastructure) planning at the city level,
- Provisions related to green spaces which e.g. increase the amount of vegetation, especially in the built-up areas of urban centers;
- Provisions related to climate and air quality which e.g. enable better air circulation; and,
- Provisions related to flood risk prevention and sustainable water management which e.g. introduce an 'index of maximal impermeableness', set up systems to collect rainwater from roofs and terraces and distribute it to infiltration and collection polders or gardens, protect vegetation on the banks of waterways.

The amount and distribution of areas covered by vegetation (not only 'formal' green areas) within the city structure are particularly important for ecosystem based adaptation capacity building. Taking Prague and Warsaw as examples, two analyses (1. land cover; 2. land use) were conducted. The aim of these analyses was to see what is the size and character of such areas and to what extent they may influence possibilities of ecosystem based capacity building.

To create land-cover maps supervised classification was used. The method allows creation of semi-automatically land-cover maps on satellite imageries. Classification were performed on satellite Landsat 5 TM multispectral imageries. The following categories were identified:

- Areas of predomination of trees;
- Areas of predomination of low vegetation; and,
- Surface water.

Land use analyses were performed on Urban Atlas data sets. From the wide range of land-use categories of which Urban Atlas consists, five were identified, with dominance of vegetation:

- Agricultural + Semi-natural areas + Wetlands;
- Forests;
- Green urban areas;
- Sport and leisure facilities; and,
- Water bodies.

4 Results and discussion

4.1 Climate change challenges and needs for adaptation capacity building in urban areas

4.1.1 Czech Republic

Climate change in the Czech Republic is regarded to be most probably a result of strengthening of the greenhouse effect of the atmosphere. That is why lowering of emissions of the greenhouse gas is a matter of the 201/2012 Law – about protection of atmosphere and related rules.

Climate protection belongs among priorities of the Czech Republic. It is the reason why new provisions to lower greenhouse gas emissions both in a general scale, and/or focused to selected problems or branches are implemented in the state policy.

A lot of provisions were approved in power engineering; energy saving products and projects are promoted in the production and consumption spheres. There are many spheres of the economy and other branches which have a close connection to the greenhouse effect – waste disposal, car industry technology, using alternative fuels and which can be improved. The Czech Republic will follow regulations and rules of the European Union to integrate railway transport and public transport in urban areas. Agricultural and forest processes and activities are supported to adapt. They can not only reduce greenhouse gas emissions, but they can also strengthen processes to bind carbon in biomass and soil.

The government has been changing trends for their improvements from using administrative tools (orders, limits, etc.) to economical tools (e.g. financial support for private house insulation improvements). It was proved that economic tools are the most effective way how to encourage population to take part in the whole process.

4.1.2 Poland

In Poland this problem is tackled in the *Strategic Adaptation Plan for Sectors and Areas Vulnerable to Climate Change to 2020 with perspective to 2030*. The plan is still under preparation by the Ministry of Environment. It means that especially its goals and recommendations may be changed as a result of public debate.

The Plan consists of information on present climatic characteristics of Poland, the changes in climate observed in 1971 - 2011, scenarios of possible changes up to 2030 and recommendations for vulnerable areas and sectors such as: water management, biodiversity, forestry, energy, coastal zone, mountains regions, agriculture, transport, spatial management and urban areas, construction, and health.

Analysis of trends in climate characteristics shows that only slight increase in air temperature is expected. However, number of days with high air temperature will increase while number of days with will decrease. There are not significant trends in the sum of rainfalls observed but rainfall frequency is going to increase. Also depositions of snowfall will decrease but large variations between successive seasons are expected. On the basis of this general prognosis the following risks are identified for urban areas in Poland:

- Reduction of space resources available for development because of floods and landslides risk, deficit of water, increase or decrease of ground water level;
- Intensification of the heat island phenomenon;
- Heavy rainfalls which caused local flooding; and,
- Periods of droughts.

The following priorities and activities have been presented for urban areas, in terms of Energy security and right state of the environment (Goal 1):

- Elaboration of development (construction) guidelines for floodplains, protected areas and green open spaces;
- Introducing restrictions in building construction on floodplains and areas endangered by landslides;
- Transfer of cultural monuments (buildings) from areas endangered by floods and landslides;
- Introducing on line access to local plans; and,
- Organization of advising bodies for investors operating on endangered areas.

And sustainable development on local and regional level with consideration of climate change (Goal 20):

- Enlargement of green areas and areas covered by water as well as ventilation corridors in development plans for urban areas;
- Elaboration of adaptation plans for cites above 100 000 inhabitants including rainwater management; and,
- Revitalization of degraded green areas including removal of impervious surface.

4.1.3 Turkey

In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) it is indicated that a 1-2°C increase in temperatures in the Mediterranean basin will be observed, that aridity will be felt in an even wider area, and heat waves and the number of very hot days will increase especially in inland regions. The average increase in temperatures is estimated to be around 2.5°C-4°C, reaching up to 5°C in inner regions and up to 4°C in the Aegean and Eastern Anatolia. The IPCC report and other national and international scientific modeling studies demonstrate that Turkey in near future will get hotter, more arid and unstable in terms of precipitation patterns. Considering the above mentioned situation of Turkey, some policies and measures for mitigating and adapting to climate change were developed. They directly or indirectly addressed green spaces and ecosystem based urban adaptation issues. The National Climate Change Strategy (2010) promotes:

- Effective use of urban land to prevent occurrence of urban heat islands;
- Increasing open and green area systems in urban areas, and developing urban forestry;

- Analysing sensitivity of urban biotopes and adopting measures to preserve them; and,
- The effective use of waste water in urban green areas.

This is complemented by recommendations in the National Climate Change Action Plan (2011) which seeks to:

- Address sustainability across land use, ecology, transportation, water management, grey water, green/white roofs etc in urban development plans; and,
- Increase the capacity of local governments to prepare and implement projects on the protection and development of urban forests and other green areas.

4.1.4 United Kingdom

The Climate Change Act 2008 legislates for climate change mitigation and adaption and sets out requirements for the Climate Change Risk Assessment and the National Adaptation Programme (NAP). The NAP 2013 defines what measures government, businesses and society are undertaking to become more climate ready and the expectation is that it will be reviewed every 5 years. Actions provided by the NAP aim to cover four broad categories which include:

- Raising awareness of our need for climate change adaptation;
- Increasing resilience to current climate extremes;
- Taking timely action for future measures; and,
- Aiming to address evidence gaps.

This is supported by the UK Climate Change Risk Assessment. The National Planning Policy Framework 2012 (NPPF) defines that local planning authorities need to work closely with their communities in order to proactively plan for climate change adaptation. There is also a statutory duty requiring local authorities to include local planning policies which help enable them adapt to climate change. For example, local planning authorities are requested to steer development away from areas of flood risk. New development should only be permitted if it will be safe and resilient to flooding and these should not increase flood risk elsewhere. Local plans are required to be supported by a Strategic Flood Risk Assessment which will also take the impacts of climate change into consideration.

4.1.5 Summary

In all surveyed countries climate change is being recognized as an important political issue. Generally, special plans or strategies have been prepared (in Poland it is still in a preparation phase) at national level in order to mitigate or / and adapt to expected changes. In case of the Czech Republic one can find dominance of the mitigation measures. In Polish and Turkish approaches the need for implementation of adaptation measures has been also observed. In those cases protection and development of green areas and urban forests are considered as essential measures. In the United Kingdom there is not only a national policy but also legal regulation (The Climate Change Act 2008). For example, Section 59(1) of the act states that “Each report of the Committee on Climate Change under Section 36 to which this Section applies must contain an assessment of the progress made towards implementing the objectives, proposals and policies set out in the programmes laid before Parliament under Section 58 (adaptation to climate change)” (UK Parliament, 2008, p 29).

4.2 Legal basis for implementation of planning measures aimed urban ecosystem-based adaptation capacity

Analytical information on which the following evaluation was based contains Table 4.2.2. The comparison of legislation which may relate to or create a basis for ecosystem based measures aimed to build or/and enhance cities' ecosystem based adaptation capacity shows the following situation:

- Law on Nature / Landscape Protection: in case of Czech Republic and Turkey it concentrates first of all on nature protection and protected areas (in Czech Republic – on ecological network creation named System of Ecological Stability); in Poland as well as in United Kingdom this legislation, besides rules of protected areas establishment and management, refers also to green spaces (or green infrastructure – UK) protection and development.
- Environmental protection: only in case of Poland there is a significant regulation which supports development of green spaces (because of their ecological values) while local plan is being elaborated [it requires establishment of biologically vital area (covered by vegetation) minimal size in relation to plot size]; in case of other surveyed countries, regulations which support adaptation capacity building have not been found; in case of Czech Republic there is no separate act for environmental protection.
- Water management: only in case of Czech Republic legislation requires taking care of vegetation alongside the watercourses; in other surveyed countries there is no regulations which could be considered as supportive for building ecosystem based adaptation capacity of cities to climate change.
- Air protection: in two countries (Czech Republic and Turkey) there are separate acts on air protection but they do not include regulations related to ecosystem based measures; in Poland as well as in United Kingdom there are no separate acts on air protection.
- Climate change: only in case of United Kingdom there is a separate legislation which tackles the issue of climate change, however it does not relate to ecosystem based adaptation capacity of cities to climate change directly
- Development planning¹⁰: in case of Czech Republic and Turkey there is no separate legislation related to this issue; in Poland and United Kingdom such legislation exists but it does not include support to ecosystem based adaptation capacity of cities to climate change.
- Spatial planning: generally, in all surveyed countries legislation concerning spatial planning contains enumeration and sometimes definitions of green areas and areas protected because of their natural values (usually resulting from vegetation cover); no other regulations were found which are likely to support ecosystem based measures creation and implementation.
- Building: only in Poland there is a regulation¹¹ which gives legal definition of the ratio of biologically vital area (RBVA - expressed the ratio between areas covered by vegetation or open water to the plot size) and sets minimum size of the RBVA for housing and health services.
- Government/governance: only in case of Polish legislation there is a statement that development and maintenance of green spaces are among the public tasks of local self-governments.

¹⁰ Taking into account that in different countries various concepts and relations between development and spatial planning occur we focus here on legislation which refers to social and economic issues first of all.

¹¹ This is derived from the Environmental Protection Act 2001 which states that in spatial planning documents in order to enhance environmental performance and living conditions the proper proportion between green and built-up areas must be established.

Analysis of legal acts being in force in surveyed countries revealed that there are no particular regulations which could be directly interpreted as a support for ecosystem based measures which enhance climate change adaptation capacity of cities. The only exception seems to be United Kingdom. In PPS 25: Development of Flood Risk (2010) one can find support for ecosystem based measures: *...mitigation of and adaptation to climate change through measures such as wetland creation, coastal and fluvial realignment and the provision of urban biodiversity...*

In all cases green spaces (or green areas or green infrastructure) and areas protected because of their natural values become a subject of more or less extended regulations but – besides United Kingdom – that does not mean that their role and importance for adaptation urban areas to climate change have been recognized and appreciated.

4.3 Measures for ecosystem-based adaptation capacity building in development strategies

Provisions or their descriptions on which the following evaluation was based contain Table 4.2.3. In all surveyed cities there are documents which contain aims and rules of development (referred to social and economic issues). In those documents, besides Izmir, one can find provisions which tackle need of protection areas with high natural values as well as green spaces development. In case of Prague provisions refer mostly to nature protection areas. In case of Warsaw and Gaziantep the problem of green spaces development, management and enhancement is raised. In case of Sheffield this general document directs to more detailed Green and Open Space Strategy.

In analyzed provisions one can find very general approach to air protection in all surveyed cities. In case of Sheffield (green spaces) and Izmir (continuity of sensitive ecosystems) provisions could be interpreted as first step to ecosystem based approach to adaptation capacity to climate change building, however it is difficult to find direct prove to this statement in surveyed documents.

Provisions related to water management which could be described as “ecosystem based measures” were traced in development strategies of Prague, Sheffield and Warsaw. They refer to recognition of the role of green spaces, vegetation or natural areas in protection and / or improvement of water management.

4.4 Measures for ecosystem-based adaptation capacity building in spatial planning

Provisions or their descriptions on which the following evaluation was based contain Table 4.2.4. Spatial planning should be considered as a main tool for implementation of discussed kind of measures. Traditionally spatial policy and spatial plans tackle the issue of green spaces development and protection of areas with natural values. However, as the analysis revealed, the problem of their meaning for building adaptation capacity to climate change is less obvious for planners and policy makers. That is visible in provisions related to green areas in all surveyed cities. In case of Sheffield, however, there are two documents: one dedicated to green infrastructure planning and second dedicated to climate protection. In both documents the role of green infrastructure or its particular elements for capacity building was underlined.

Climate protection and air quality is the subject of spatial planning documents in all surveyed cities. However, provisions refer first of all to air pollution limitation. In Warsaw also the need for

maintaining or creation air flows corridors is mentioned (this provision is based on recommendation resulting from Urban Natural System concept).

In provisions related to water management in case of Prague and Warsaw some ecosystem based measures were traced (e.g. protection and use of natural areas, especially wetlands, existing ponds, oxbows lakes and clay pits to storage (retention) of rainwater – Warsaw, improvement of retention ability of water streams using natural phenomena – Prague). It should be underlined, however, that in both cases provisions are too general to be implemented directly.

4.5 Measures for ecosystem-based adaptation capacity building in environmental protection policy

Table 4.2.5 summarises the information on which the following evaluation was based. First of all it should be mentioned that due to the differences in planning systems of surveyed countries only in Poland and Turkey such documents are being elaborated. In Czech Republic and United Kingdom environmental protection usually becomes a subject of general development strategy.

Only in the case of Warsaw provisions included into the document refer to green spaces protection and development. However, no particular attention is paid to the role of green spaces in adaptation of the city to climate change. In case of Izmir - establishment of protected area and Gaziantep - afforestation strategy becomes the main subject of recommendations.

4.6 Measures for ecosystem-based adaptation capacity building in climate protection policy

The following evaluation was based on details summarised in Table 4.2.6. Only in the cases of Sheffield and Gaziantep were such planning documents were adopted. Both recognize green spaces or green infrastructure as an important measure for adaptation capacity building in individual cities. In Sheffield provisions concentrate first of all on green roofs (document recommends their development), in Gaziantep plantation of trees accompanying bicycle routes is promoted.

4.7 Measures for ecosystem-based adaptation capacity building in green space development and green infrastructure policy

It should be underlined that only in case of Sheffield there is separate document entitled '*Green and Open Space Strategy 2010-2030*'. It sets out the long-term strategy for the future use and management of the city's green and open spaces. The Strategy is centered around four key themes:

1. People.
2. Places.
3. Environment & Sustainability.
4. Quality Management.

The climate change issue is raised as the first in policy statements of Theme 3 (Environment & Sustainability). The *Strategy* recommends:

- To manage a network of urban 'green links' for nature conservation that link in with regional nature conservation corridors;

- To connect communities to Sheffield's urban and rural green and open spaces by a network of attractive walking and cycling routes - 'green connections';
- To manage green and open spaces in a way that allows them to adapt to a changing climate while enabling them to continue to deliver their primary public benefits;
- To plan and manage the collective contribution of Sheffield's green and open space network, as part of the city-wide strategic response to Climate Change; and,
- To promote opportunities for public participation in Sheffield's response to Climate Change.

4.8 Ecosystem-based adaptation capacity building: green space potential in Prague and Warsaw

Land cover, performed on the basis of Landsat imagery, allows identification of areas covered by vegetation (Figure 4.2.1, Table 4.2.2). It also shows the vertical structure of the vegetation (and surface water) on identified areas.

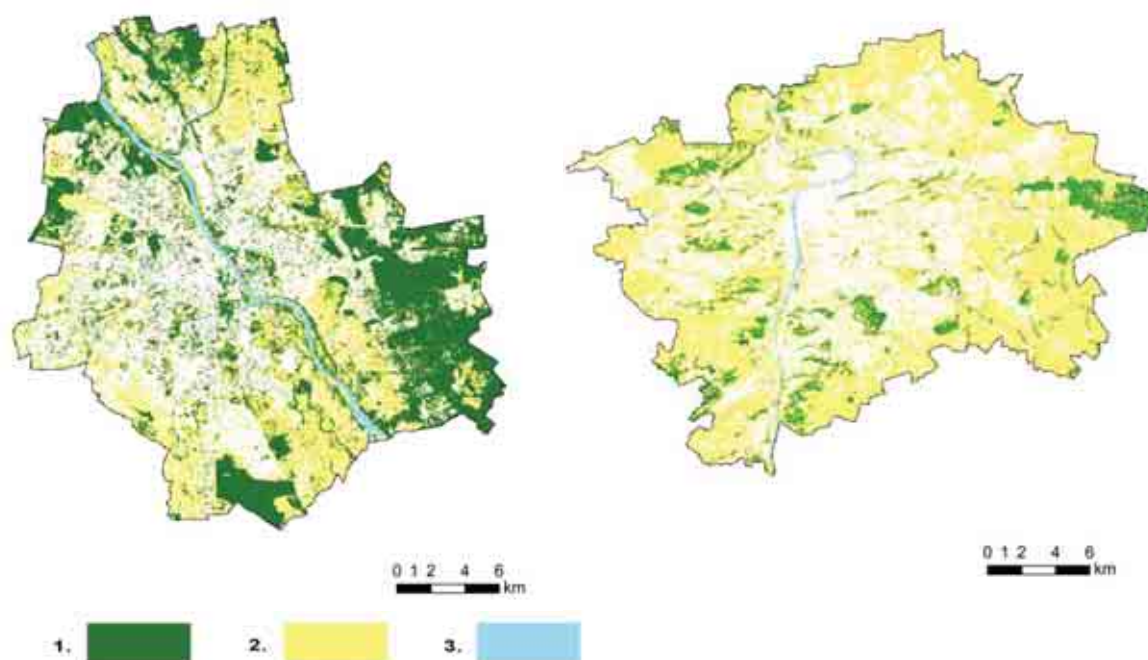


Figure 4.2.1 Comparison of green infrastructure land cover spatial distribution of Warsaw and Prague. Areas dominated by 1. substantial tree cover, 2. low vegetation, 3. surface water.

Table 4.2.2 General characteristics of green infrastructure land cover for Warsaw and Prague.

	City area km ²	Green areas								Built-up areas	
		Surface water km ²	%	Low vegetation km ²	%	Trees %	km ²	Total km ²	%		
Prague	496.00	2.80	0.56	264.52	53.33	39.05	7.87	306.37	61.77	189.63	38.23
Warsaw	517.24	7.80	1.51	259.75	50.25	75.43	14.59	342.98	66.35	173.92	33.65

Green areas land-cover in both analyzed cities shares similar area – 66.35 % in Warsaw and 61.77 % in Prague. However, the area of particular green spaces categories varies. In both cities there is predomination of low vegetation (agricultural land, meadows, lawns), but the proportion is quite different. In Warsaw low vegetation covers ca 260 km², which represents 50% of the city area, and 76% of all open spaces. In Prague low vegetation constitutes 53% of the city area, but as much as

85% of all green spaces. There is a significant difference in share of areas of trees predomination. Warsaw is covered by trees (forests, parks etc.) in almost 15%, but Prague has almost half of it (near 8%). Some inaccuracies may be caused by spatial distribution of the trees (classification works better with homogeneous land cover) but land-use analysis confirms this result. And last, but not least, surface water, which is an important element in both cities. Warsaw and Prague are located by rivers, which are there the most important hydrological elements in spatial development, but all in all water covers slightly more than 1.5% in Warsaw and 0.56% in Prague.

Land use structure of green areas is a second part of comparison, which shows main functions of green spaces (Figure 4.2.2, Table 4.2.3). On its basis it may be possible to estimate durability of spatial development – to assess which areas have less chance to outlast as open spaces.

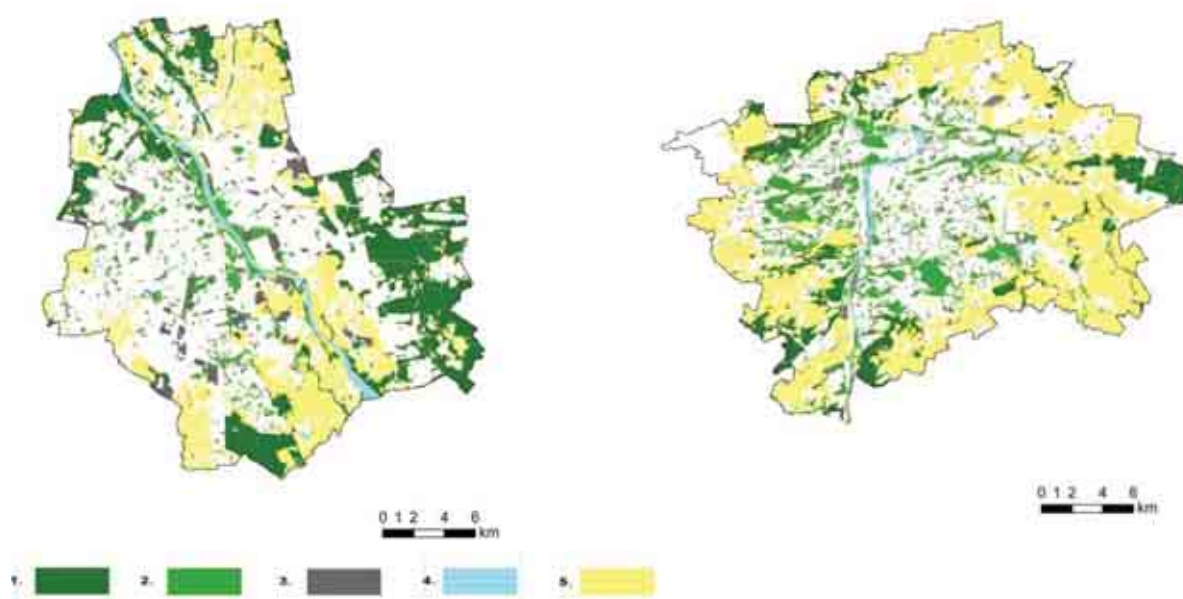


Figure 4.2.2 Comparison of green space use in Warsaw and Prague. 1. Forests, 2. Urban green areas, 3. Sport and leisure facilities, 4. Water, 5. Agricultural and semi-natural areas and wetlands.

Table 4.2.3 General characteristics of green infrastructure land use for Warsaw and Prague.

	City area (km ²)	Agricultural areas (%)	Green areas (%)	Green areas			Total (%)	Built-up areas (%)
				Forests (%)	Sport and leisure (%)	Water (%)		
Prague	496,00	33,87	9,33	9,47	2,66	1,5	56,82	43,18
Warsaw	516,90	18,99	4,74	17,84	4,23	2,29	48,09	51,91

Green areas land-use structure is more diversified between both analyzed cities than land-cover. Green areas represent 57% of Prague and 48% of Warsaw. From selected categories the largest part of the city area are agricultural and semi-natural areas (and wetlands), but in Prague it is near 34%, and in Warsaw only 19% of the city area. Second most important are forests, in which case differences between both cities are also clear: Warsaw holds near 18% of forest, but Prague – only 9,5%. It is important to mention that this category contains forest in recreational use, and does not include housing areas in forest (included into other category). Sport and leisure facilities and water have the least impact on the total green spaces share in both cities.

The analysis shown above presents that a similar share of green areas in total overview, not always means the same in particular. Both cities have a similar share of green spaces land-cover, in

Warsaw slightly larger. In land-use approach the result is reversed. It means that some areas in Prague which are included into “green” categories in Urban Atlas in fact are built-up in large parts. In Warsaw some built-up areas have a large share of green space, which increases results of land-cover analysis.

Besides the problem of green spaces identification and determination of their precise quantity, the analysis shows the enormous potential which they create in surveyed cities. In both cases more than half of their area is covered by vegetation and water. That may and should be considered as a potential also for ecosystem based capacity building. This potential depends not only on the size of ‘green patches’ but also on their distribution within the city.

In case of Prague and Warsaw one can notice a situation rather typical for a prevailing number of cities: areas covered by vegetation (usually agricultural areas and forests) are located in the outskirts. However, some green corridors or green wedges penetrating urban structure are visible. Those should be protected against development due to their role also¹² for regulating climate and hydrological conditions. From an adaptation point of view extremely important are ‘green patches’ situated in densely built-up areas. They should be not only protected but also re-designed and modernized in such a way that besides main social functions they could perform their environmental function well.

One cannot say that these facts are unknown to planners. Still, however, in planning practice the role of green infrastructure in adaptation of urban areas to climate change seems to be underestimated.

5 Conclusions

The results of our analysis and comparisons revealed that:

1. Our assumption that we could expect different approaches, within surveyed cities to the implementation of planning measures for adaptation to climate change was not definitively confirmed. Expected differences between cities resulting from their various climatic conditions were not traced. This may be explained by: 1) the very general level of provisions typical for planning documents elaborated on the city level; and/or, 2) a lack of expertise concerning the character of the needs for adaptation measures implementation. This last statement would not appear to apply to Sheffield, which represents an advanced approach with two complementary planning documents tackling the ecosystem based adaptation issue: *Green and Open Space Strategy* and *The Climate Change and Design Supplementary Planning Document*. However, a gap analysis between local policy and practice is an important area for further work.
2. In all surveyed countries the problem of climate change consequences for nature, economy and society has been recognized. Governments seem to be well aware about climate protection needs, implementation of climate change mitigation and adaptation measures included. Potentially the importance of anticipated climate change impacts in United Kingdom to its advanced development of climate mitigation and adaptation regulations and policies.
In national documents related to climate change of Turkey (2011) and Poland (Plan still under preparation) recommendations concerning need for adaptation measures could be found. The scope of these recommendations is similar while geographic situation and climatic conditions of both countries differ.

¹² Their protection and /or creation is often justified for biodiversity enhancement (e.g. as migration corridors)

3. Legal acts which are in force at the moment and regulate such matters as nature, landscape and environmental (water, air and climate included) protection do not fully 'see' the problem. For example, recommendations for the protection of green areas or areas' important natural value generally result from concerns over their conservational or social values. So, taking into account that protection and enhancement of all types of green spaces in cities constitute potential for implementation ecosystem based measures, contemporary legislation – in surveyed countries – can be regarded as supportive.
Direct requirements to implement climate change ecosystem based measures are included into legal regulations only United Kingdom in: *Flood and Water Management Act* 2010, *Environment Act* (1995, with amendments), PPS 25 *Development of Flood Risk* (2010).
4. Surveyed policy statements and/or provisions generally refer to development and enhancement of green spaces and protection of areas with high natural values in urban areas. However, the full potential of these areas for adaptation of cities to climate change – besides Sheffield – has not been recognized yet or perhaps is emergent in Warsaw. This means that the main goals of green spaces protection and development often refer first of all to independent social and ecological needs in the surveyed cities.
5. Policy statements and/or provisions which concern climate and air quality, flood risk prevention and sustainable water management, are present in surveyed planning documents, but only to some extent and consider ecosystem based measures quite generally. Only in Sheffield and Gaziantep there are separate planning documents dedicated to climate protection.
6. In all surveyed cities – except Sheffield – there seems only to be a general awareness of the need for adaptation to climate change. Suggested measures (identified on the basis of analyzed planning documents provisions) do not reveal individual approaches based on the situational and specific adaptation problems of the city. They seem to be based rather on general academic knowledge than on an individual climate change risks assessment in surveyed cities. In depth analysis of projected problems and an evaluation of existing green spaces from the adaptation capacity to climate change point of view would be recommended
7. Green spaces, or rather areas covered by vegetation that exist in cities, constitute – because of their share in cities' area – big potential for introducing ecosystem based measures for climate change adaptation capacity building. But it seems that only in Sheffield this potential starting to be utilized by planners and politicians for addressing climate change in its strategic vision. In other surveyed cities this issue still seems to be underestimated.
8. Green infrastructure ideas in which the integration of many functions of areas covered by vegetation and water are strongly recommended and offer a new opening for urban green space planning. Of course, understanding of the different roles played by green spaces has been present amongst landscape architects and planners for a number of decades. However, there is a now significant need for this understanding to start influencing political and policy agendas because of its meaning.

Table 4.2.4 Legal basis for implementation ecosystem based measures for adaptation of urban areas to climate change.

Country	Czech Republic	Great Britain	Poland	Turkey
Nature / landscape protection	<p>Nature and Landscape Protection Act (1992):</p> <ul style="list-style-type: none"> - Defines Land System of Ecological Stability (LSES) as a set of interconnected natural or semi-natural ecosystems maintaining natural balance; - Defines two main elements of the System: bio-centrums and bio-corridors; - Recommends protection of important landscape elements (edges of forest stands, line vegetation around water flows, important solitaire or group greenery in urban areas); - Defines rules for urban planning with no extra regulations concerning greenery; - Defines rules regarded LSES implementation; - Defines content of landscape planning basic data and documents and their approval (depending on geographical levels – city, region) 	<p>Environment Act 1995; PPS 9 Biodiversity and Geological Conservation (2006):</p> <ul style="list-style-type: none"> - Recognizes green infrastructure as crucial for biodiversity conservation. - The first key principle of PPS9 reflects the requirement set out in paragraph 19 of PPS1 that plan policies and planning decisions should be based on up-to-date information about the environmental characteristics of an area. PPS9 makes clear that these characteristics should include the relevant biodiversity and geological resources. - Defines the requirement to create regional and local Biodiversity and Geodiversity Action Plans. 	<p>Nature Conservation Act (2004 with amendments)</p> <ul style="list-style-type: none"> - Sets rules for different types of nature protected areas establishment and management; - Defines green spaces as all areas covered by vegetation; - Defines functions of green areas (but their role as adaptation to climate change is not mentioned); - Defines categories of green areas (e.g. parks, green squares) - Green areas are considered as one of the objects of nature conservation in cities 	<p>Law on the Conservation of Cultural and Natural Property (1983 with amendments):</p> <ul style="list-style-type: none"> - Defines movable and immovable cultural and natural property to be protected; - Defines conservation sites as an area the natural characteristics of which have been documented to require protection.
Environmental protection	<p>Landscapes and Nature Protection Act (40/1956, updated by 114/1992 Act (defines Land Systems of Ecological Stability LSES)</p>	<p>Environment Act (1995):</p> <ul style="list-style-type: none"> - Establishes regulating bodies for contaminated land, national parks, control of pollution, conservation of natural resources, conservation or enhancement of the environment 	<p>Environmental Protection Act (2001 with amendments)</p> <ul style="list-style-type: none"> - Requires establishment of biologically vital area (covered by vegetation) minimal size in relation to plot size while local plan is being elaborated; - Considers green areas as one of the basic elements that should be taken into consideration while solving the problems of urban areas development 	<p>Environment Act (1983):</p> <ul style="list-style-type: none"> - No regulations related to ecosystem based measures
Water management	<p>Water Act (2001):</p> <ul style="list-style-type: none"> - Protection of ground and surface water; - Creates conditions for lowering impacts of floods and droughts; - Defines duty of water management to take care of vegetation alongside the watercourse 	<p>Flood and Water Management Act 2010; Environment Act (1995); PPS 25 Development of Flood Risk (2010)</p> <ul style="list-style-type: none"> - Sets out policy on development and flood risk in response to Flood and Water Management Act. - Resulting national strategy states that the maintenance and restoration of a range of ecosystem services, or natural functions of the environment, can provide valuable additional benefits including: <ul style="list-style-type: none"> o water quality improvements through reductions in run-off and diffuse pollution; o water resource provision through aquifer recharge; o mitigation of and adaptation to climate change through measures such as wetland o creation and coastal and fluvial realignment, o -the provision of urban biodiversity 	<p>Act on water (2001 with amendments)</p> <ul style="list-style-type: none"> - No regulations related to ecosystem based measures 	<p>Regulation on Water Pollution Control (2004):</p> <ul style="list-style-type: none"> - No regulations related to ecosystem based measures
Air protection	<p>Air Protection Act (2002 with amendments):</p> <ul style="list-style-type: none"> - No regulations related to ecosystem based measures 	<p>Environment Act (1995) - Local Air Quality Management (PG09)</p> <ul style="list-style-type: none"> - Policy Guidance for local authorities in England to carry out local air quality management through Air Quality Action Plan (AQAP). - AQAP typically consider the importance of cycleways and cycle to work schemes and mitigation measures relating to driving habits. 	<p>There is no separate act for air protection</p>	<p>Regulation amending the Regulation on Air Quality Assessment and Management (2009)</p> <ul style="list-style-type: none"> - No regulations related to ecosystem based measures

Climate change	There is no separate act for climate change	Climate Change Act (2008): Requires the Government to assess the UK's risks from climate change, prepare a strategy to address them, and encourage critical organisations to do the same.	There is no separate act for climate change	There is no separate act for climate change
Development planning	There is no separate act for development planning	Town and Country Planning Act (1990); Town and Country Planning (Scotland) Act (1997); Planning and Compulsory Purchase Act (2004); Planning Act (2008) PPS9 defines that there is a need to appraise environmental impacts of all development proposals, including the requirements of the Environmental Impact Assessment Regulations (EIA Regulations) and the Habitats Regulations	Act on Development Policy Principles (2006): No regulations related to ecosystem based measures	There is no separate act for development planning
Spatial planning	Urban Planning Act (1976 with amendments): Defines and recommends protection of greenery in national parks, protected landscape areas, natural reserves, natural monuments and recreational areas and zones.	PPS 12 Local Spatial Planning (2008): Sets out what local spatial planning is the key components of local spatial plans. This includes a requirement to address the 'physical, social and green infrastructure'; PPG 17 Planning for Open Space, Sport and Recreation (2006) Describes the role of the planning system in assessing opportunities and needs for sport and recreation provision and safeguarding open space.	The Act on Spatial Planning and Development (2003) Ordinance on Required Scope of the Local Plans (2003) Defines categories of green spaces (nature conservation areas, forests, urban parks, allotment gardens, cemeteries) to be considered in local plans; Regulation for the Areas with Development Plan (1985-2008): Defines categories of green areas (parks, regional parks, playgrounds, gardens for kids, botanical and zoological gardens, fair areas, picnic areas, coastal areas). Regulation for Principles of Creating Plans (1985-2001): - Defines categories of green areas (parks, playgrounds, and gardens for kids) - Defines the amount of green area per person (10 m2 / person)	
Building	Building Act (2006): No regulations related to ecosystem based measures	Building Act (1984) - No specific reference to ecosystem approaches, however its implementation through PPS1 and PPS9 include the need for integrated Environmental Impact Assessment.	Building Act (1994 with amendments) No regulations related to ecosystem based measures but Ordinance of the Minister of Infrastructure on technical conditions for building construction and their layout (2002) - Gives legal definition of the ratio of biologically vital area (RBV/A); - Sets minimum size of the RBVA for housing and health services Reconstruction Regulation for Areas that Have Construction Plan (1985-2008 - 2013): - Defines social and cultural infrastructure as (among others): - Green areas (playgrounds, parks, recreational areas), sport areas, cemeteries.	
Government/ Governance	There is no separate act for government/ governance	PPS 1 Delivering Sustainable Development (2005): Eco-towns is a supplement to PPS1 and states: that eco-towns achieve sustainability standards significantly above equivalent levels of development in existing towns and cities by setting out a range of challenging and stretching minimum standards for their development, in particular by: - providing a good quantity of green space of the highest quality in close proximity to the natural environment - enabling opportunities for infrastructure that make best use of technologies in energy generation and conservation in ways that are not always practical or economic in other developments.	Local Self-government Act (1990): - Development and maintenance of green spaces is one of the public tasks of local self-governments	There is no separate act for government/ governance

Table 4.2.5 Development strategies relevant to green infrastructure in case study cities.

City	Prague	Sheffield	Warsaw	Izmir	Gaziantep
Planning documents	Strategic development plan for 10 – 15 years (2008)	Sheffield Development Framework (2010)	Warsaw Development Strategy 2020 (2005)	Izmir Regional Plan 2010-2013 (2010)	Gaziantep Regional Plan 2011-2030
Description of planning document (aims, scope)	It analyzes present state and summarizes general socio-economic, environmental, safety, infrastructure, management and development rules including their control	The framework comprises of the following documents: - Statement of Community Involvement; - Core Strategy: Adopted; - City Policies: Emerging Options; - City Sites: Emerging Options; Emerging Proposals Map; - City Policies: Preferred Options; - City Sites: Preferred Options; Proposal Map: Preferred Options; - Climate Change and Design SPD and Practice Guide	- It concentrates on five strategic goals: o life quality and safety; o identity and tradition; o metropolitan functions; o knowledge based economy; o spatial order	It aims to create a background for the effective and efficient use of the potential of Izmir by providing the strategic planning works and institutional and sectoral strategy documents	It analyzes, formulates and describes socio-economic, environmental, and sectoral development strategies. The document has temporal and spatial dimensions.
Provisions related to green areas (green infrastructure)	<ul style="list-style-type: none"> - Protection green areas insured by: o setting up of 8 European important locations (most of them are protected (NATURA 2000); o 89 small size green protected area of the special importance (4% of the Prague area), which are parts of 11 natural parks (20% of the Prague area) 	<ul style="list-style-type: none"> - Within the main framework documents there are the Green and Open Space Strategy 2010-2030 	<ul style="list-style-type: none"> - Protection of green areas system and natural landscape's elements (Warsaw Escarpment; Vistula Valley). - Construction of new parks (enumerated) - Enhancement of ecological connectivity by ecological corridors protection - Revalorization of historic parks 	<ul style="list-style-type: none"> - Ensures the improvement and control of air quality (supporting the use of renewable and clean energy resources in industry and home heating, providing air quality control in heavy industrial zones); - Ensures continuity of Sensitive Ecosystems and Biodiversity (protection of biodiversity) 	<ul style="list-style-type: none"> - Protection and improvement of green areas; - Maintenance the continuity of green structure and its components.
Provisions related to air quality	<ul style="list-style-type: none"> - Air quality is processed within 6th key environmental area as the nature and landscape area item; - Vision of the city is to maintain healthy environment for inhabitants and maintain or improve air quality - Reducing of the air pollution according to valid limits of pollution, lowering of noise, especially in residential and recreational areas 	<ul style="list-style-type: none"> - The Core Strategy outlines a policy need for action to protect air quality in all areas of the city; green space as well as transport planning are recommended as a significant mechanisms for tackling and improving air quality. 	<ul style="list-style-type: none"> - Protection air follow corridors by restrictions in building permissions issuing on the areas situated within borders of this corridors 	<ul style="list-style-type: none"> - Air quality in and around the city should be improved during all year by using technical and natural measures. Green technology and green spaces planning approaches should be used. Human and ecosystem needs should be meet by using sustainable planning methods. 	
Provisions related to water management	<ul style="list-style-type: none"> - Revitalization of water surface; - Regular maintenance of water beds and coasts to enhance biodiversity a create new biocentres; - Improve of water streams retention ability of using natural phenomena - Creation of new water ponds to improve microclimatic conditions 	<ul style="list-style-type: none"> - Core Strategy states that the extent and impact of flooding will be reduced by both green and blue planning measures. 	<ul style="list-style-type: none"> - Enhancement and protection of natural character of right bank of the Vistula River. 	<ul style="list-style-type: none"> - Ensures the sustainable water and waste water management in basin areas, areas with tourism potential and rural areas. 	<ul style="list-style-type: none"> - Water basins and streams should be protected from the threats of desertification and urbanization; - protection plans should be supported by studies concerning possibility of green spaces development .

Table 4.2.6 Spatial planning and spatial policies relevant to green infrastructure in case study cities.

City	Prague	Sheffield	Warsaw	Izmir	Gaziantep
Title of the document	Rules of land development (2010)	Core Strategy (2009)	Warsaw's Study of Development Conditions and Directions (2006, amended in 2010)	Urban-Region Development Revision Plan Explanation Report (2009)	Integrated Urban Development Strategy and Action Plan (2010)
Description of planning document (aims, scope)	General planning document for regions (Prague is a region level unit) with 4 years update)	Sets of spatial planning framework for Sheffield including land use preferred options and site allocations	It's elaboration is required and regulated by the Act on Spatial Planning and Development (2003). It's aims is to present spatial policy of the city of Warsaw	This plan has been revised according to the Manisa-Kutahya-Izmir Planning Region Environmental Plan and focuses on directing urban development for protecting cultural and natural values by 2030. (1:25 000 scale)	The plan aims at formulating the spatial planning strategies.
Provisions related to green areas (green infrastructure)	Delineates corridors of ecological stability defined by Edict on the Landscape Planning Fundamentals and Landscape Planning Documentation – as important green areas, water surfaces, above-regional biocorridors, regional corridors, above regional bio-centres, regional biocentres	Green and Open Strategy 2010-2030 within this framework sets out the long-term strategy for the future use and management of the city's green and open spaces.	Establishes Natural System of Warsaw; (areas included into the System are meant to be responsible for environmental performance of the city; system consists of core areas important for sustaining climatic conditions, hydrological and ecological, processes;	Establishes protected areas according to the protection value of the area such as national park, nature park, Ramsar Site, Biosphere Reserve etc.	Establishes strategies for: sustainable open and green areas, planning and design standards for open and green areas, developing city forests
Provisions related to climate and air quality	<ul style="list-style-type: none"> - Vision of the city is to maintain healthy environment for inhabitants and maintain or improve air quality - Provisions specified policy for air quality by lowering of number of cases with values exceeding limits of pollution per year 	<ul style="list-style-type: none"> - Core strategy focuses on urban areas, and where pollution exposure to residents may be above national targets due to their proximity to traffic/road corridors. - Core strategy focuses on urban areas, and where pollution exposure to residents may be above national targets due to their proximity to traffic/road corridors. 	<ul style="list-style-type: none"> - Establishes air flow corridors as a part of supporting areas of Warsaw Natural System, - Defines rules of air flow corridors development, e.g. there are not allowed investments which may adversely affect the quality of air, - Recommends management of the area in a manner which promotes the exchange of air 	<ul style="list-style-type: none"> - Supports the use of renewable energy resources such as solar, wind and geothermal 	<ul style="list-style-type: none"> - Recommends use of environment friendly technologies in selection of fuel and vehicles types used in public transport.
Provisions related to water management	<ul style="list-style-type: none"> - Revitalisation of water surface – landscape and recreational-esthetic function - Regular maintenance of water beds and coasts to enhance biodiversity a create new biocentres - Improvement of retention ability of water streams using natural phenomena - Improvement of microclimatic conditions by new water objects - Improvement of surface and ground water quality, -rehabilitation of the water surface role in landscape 	<ul style="list-style-type: none"> - Blue planning measures are focused upon maintaining and increasing open courses through reduction of culverting and water-compatible land uses. For example: - Not culverting and not building over watercourses wherever practicable; - Encouraging the removal of existing culverting; - Developing only water-compatible uses in the functional floodplain; - Developing areas with high probability of flooding only for water-compatible uses unless an overriding case can be made and adequate mitigation measures are proposed 	<ul style="list-style-type: none"> - Restoration of water systems and water courses - Maintenance of riparian forests - Providing optimal conditions for supply of watercourses - Storage and slow rainwater runoff - Protection and use of natural areas, especially wetlands, existing ponds, oxbows lakes and clay pits to storage (retention) of rainwater; - Reduction of sealed surfaces; - Maintaining the maximum share of biologically vital areas in areas dedicated to development. 	<ul style="list-style-type: none"> - Defines protection status of water basins, water resource protection areas and wetlands; - Defines the borders of water collecting basins of dams; - Defines the planning criteria related to use and construction of current, short, medium and long distance water resource protection zones; - Defines the flood risk areas of rivers 	<ul style="list-style-type: none"> - The storage and the use of rainwater for urban works

Table 4.2.7 Environmental protection policy relevant to green infrastructure in case study cities.

City	Prague	Sheffield	Warsaw	Izmir	Gaziantep
Title of the document	There is no separate document dedicated to environmental protection; this issue is tackled in Strategic development plan for 10 – 15 years (2008)	Environmental protection is addressed within the Core Strategy (2009) Environmental and spatial planning are complementary and brought together within the Sheffield Development Framework and Core Strategy	Environment Protection Program (2009)	Manisa-Kutahya-Izmir Planning Region Environmental Plan (2010)	Environment Report (2011)
Description of planning document (aims, scope)	The Core Strategy is the first of a range of documents which make up the Sheffield Development Framework and sets out the overall vision, objectives and spatial strategy and policies for Sheffield over the period to 2026. Within the framework there is: <ul style="list-style-type: none"> - Carbon Reduction Action Plan - Environmentally Sustainable Housing Strategy - De-centralised Energy Strategy - Carbon Reduction Framework - Climate Change Adaptation Strategy 	<p>The Core Strategy is the first of a range of documents which make up the Sheffield Development Framework and sets out the overall vision, objectives and spatial strategy and policies for Sheffield over the period to 2026. Within the framework there is:</p> <ul style="list-style-type: none"> - Carbon Reduction Action Plan - Environmentally Sustainable Housing Strategy - De-centralised Energy Strategy - Carbon Reduction Framework - Climate Change Adaptation Strategy 	Environment Protection Program is a comprehensive strategy of environment protection. Under regulations of Environment Protection Act, each municipality is obliged to prepare and update such document every four years.	Plan focuses on eliminating the problems caused by rapid and uncontrolled urbanization, ensuring controlled urban and industrial development, promoting sustainable development, preventing potential impacts which disrupts the ecological balance and by 2025 (1:100 000 scale)	It contains the inventory and descriptions of the areas which are ecologically sensitive. It also contains important data for regional biodiversity. It formulates the protection and management strategies for natural areas.
Provisions related to green areas (green infrastructure)	Green and Open Space Strategy	<ul style="list-style-type: none"> - Carbon Reduction Action Plan - Environmentally Sustainable Housing Strategy - De-centralised Energy Strategy - Carbon Reduction Framework - Climate Change Adaptation Strategy 	<ul style="list-style-type: none"> - Conservation and proper use of natural heritage; - Creation of interconnected system of urban green areas providing different recreational facilities; - Preservation of forests for biodiversity conservation; - Maintaining integrity of Warsaw Natural System - Green areas are recognized as a means of: mitigation the adverse impact of transport system and industry, quality of life improvement. 	<ul style="list-style-type: none"> - Establishes protected areas according to their conservation values (national park, nature park, Ramsar Site, Biosphere Reserve etc) 	<ul style="list-style-type: none"> - Formulates the outlines of regional and city scale afforestation strategies.
Provisions related to climate and air quality	<ul style="list-style-type: none"> - Carbon Reduction Action Plan - Environmentally Sustainable Housing Strategy - De-centralised Energy Strategy - Carbon Reduction Framework - Climate Change Adaptation Strategy 	<ul style="list-style-type: none"> - Carbon Reduction Action Plan - Environmentally Sustainable Housing Strategy - De-centralised Energy Strategy - Carbon Reduction Framework - Climate Change Adaptation Strategy 	<ul style="list-style-type: none"> - Conservation and proper use of natural heritage; - Creation of interconnected system of urban green areas providing different recreational facilities; - Preservation of forests for biodiversity conservation; - Maintaining integrity of Warsaw Natural System - Green areas are recognized as a means of: mitigation the adverse impact of transport system and industry, quality of life improvement. 	<ul style="list-style-type: none"> - Establishes protected areas according to their conservation values (national park, nature park, Ramsar Site, Biosphere Reserve etc) 	<ul style="list-style-type: none"> - Formulates the outlines of regional and city scale afforestation strategies.
Provisions related to water management	Water Management Strategy in progress	Water Management Strategy in progress	<ul style="list-style-type: none"> - Requirement of enhancement of natural retention, taking into considering flood risk issues while preparing local plans 	<ul style="list-style-type: none"> - Indicates protection status of water basins, water resource protection areas and wetlands 	<ul style="list-style-type: none"> - Indicates protection status of water basins, water resource protection areas

Table 4.2.8 Climate protection policy relevant to green infrastructure in case study cities.

City	Prague	Sheffield	Warsaw	Izmir	Gaziantep
Title of the document	There is no separate document dedicated	The Climate Change and Design Supplementary Planning Document (SPD) (2011)	Action Plan for Sustainable Energy Use in Warsaw in Prospect of 2020 (2011)	There is no separate document dedicated	Climate Action Plan of Gaziantep (2011)
Description of planning document (aims, scope)		SPD has been drafted to assist with the implementation of the adopted Core Strategy and supports the following Core Strategy policies: CS63 Responses to Climate Change; CS64 Climate Change, Resources and Sustainable Design of Developments; CS65 Renewable Energy and Carbon Reduction; and CS67 Flood Risk Management. The main area of climate change planning guidance relating to green infrastructure is its guidance on the adoption of green roofs	It concentrates on the use of energy. It contains some climate change mitigation / adaptation issues but any of them relates to ecosystem based measures		It contains measures aimed to climate change mitigation/adaptation
Provisions related to green areas (green infrastructure)					<ul style="list-style-type: none"> - Recommends reconnection of the urban area with nature: biodiversity, extensive open spaces - Points out the meaning of green areas for reduction of urban hot zones - Recommends plantation of trees on the hedge of the bike lanes to create shadow - Promotes building density and urban sprawl control
Provisions related to climate and air quality		CS65 Renewable Energy and Carbon Reduction covers measures to reduce carbon emissions Decommissioning Renewable/Low-Carbon Energy Infrastructure			<ul style="list-style-type: none"> - Points out the role car limitation policy, community parking, car-sharing, connection to public transport, walkable neighborhood, etc.
Provisions related to water management		Water Management Strategy in progress			<ul style="list-style-type: none"> - Recommends reducing water losses and energy savings in water management, reducing water consumption in general and for public buildings - Recommends sustainable urban drainage systems.

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Section IV-3

Sustainability indicators for urban water environments

Carlo Gualtieri¹, Petra Amparo López-Jiménez²

¹ Civil, Construction and Environmental Engineering Department (DICEA), University of Napoli "Federico II".
Italy. carlo.gualtieri@unina.it;

² Hydraulic and Environmental Engineering Department,
Universitat Politècnica de València, Spain. palopez@upv.es

Highlights

- This research intends to review the role of surface waters management in the urban metabolism, dealing with the general interactions of waters in the particular urban environment.
- We analyze the sustainability aspects of the surface waters systems, related to Green Infrastructures, also present in the city.
- Particularly, the parameters for river water quality indicators are presented.
- This methodology is possible thanks both to measurements in surface waters and also thanks to models. The importance of environmental fluid mechanics as a tool for determining such parameters is presented.

1 Introduction

Sustainability is a wide concept, but necessary to be applied nowadays in all the processes involving resources wasting. One of the more important of these processes is the water cycle in the cities, where water quality issues are very frequent.

River and sea water have many implications in this urban context from the primary moment of treatment, in river, bell or sea water, till the last moment of disposal as treated water; again in river or sea. Even the reuse of water is a possibility that must be considered within the whole management options in the urban environment towards sustainability. Sustainable water management is a multidimensional approach to the issue of interdependency between the natural, social and economic variables that play a role in different water uses (Menciò et al. 2010).

Sustainability indicators can be evaluated in terms of quality or quantity of an issue; however, the difference between them and other performance indicators is the focus on linkage between different sectors. In this particular case, water is a horizontal aspect of the urban management. It is present in social, economic, climatic and many other roles in the city. Therefore, any indicator of quantity or quality takes paramount importance to make policies in urban, regional or national scales.

In Section IV-3, some of the concepts related to water management in urban environments will be presented, particularly focused in those indicators of water quality in river cities.

2 Urban water in the urban metabolism

Urban metabolism not a recent concept, it was yet presented by Wolman in 1965. It is fundamental in the understanding of human communities. It can be considered as “the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste” (Kennedy et al., 2007). In fact, the practical applications of urban metabolism have many implications, among them, the urban water management, considering the whole city infrastructures concerning to water supply. And particularly, the management of the parameters indicating water quality in rivers is a determinant subject in the whole urban metabolism of the city.

Urban water systems play an important role in sustainable development considered in urban metabolism; as they deal with a fundamental human need: access to drinking water, sanitation, water quality and health.

In general, two aspects must be considered when dealing with water management in future: growing urban populations around the globe; and rising environmental awareness of society. These premises will rule the future of water management. When cities have a river for supplying surface waters, this quality must be assured from the very beginning in the treatment plant. If cities have not a river, then other water resources must be considered, such as subterranean waters, desalination or even water reutilization (Figure 4.3.1).



Figure 4.3.1 Urban metabolism related to surfaces water.

Water is a free resource for population. However, having abundant water supplies does not guarantee that water is available to meet the needs or expectations of every user. In this sense, managers have to take decisions taking into account the water resources availability (in quantity and quality) in order to manage the system in the more sustainable way, maintaining some minimum parameters.

River water quality indicators in cities are related to models, because pollutant concentrations can be calculated or even measured by the modellers. Nevertheless, the interdisciplinary character of the sustainability indicators take other implications: more social or economic determinations must be considered and the traditional models are not suitable to be used as a complete tool for evaluation of sustainability in the city. As depicted in Figure 4.3.2, water has a complex cycle in the urban environment and many technical, economic and social agents are involved.

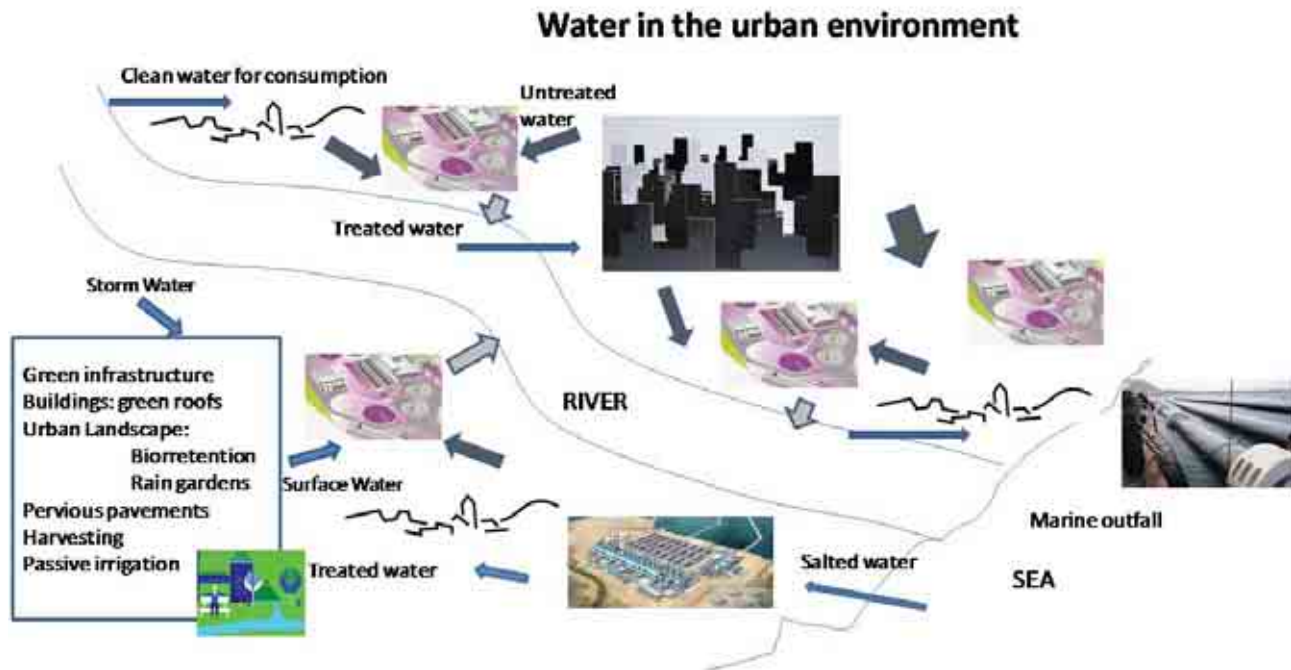


Figure 4.3.2 Water cycle in the urban environment.

But the urban water cycle is not a unique system. It is important to understand and consider all the relationships between the components of the urban system (water supply, wastewater, and storm-water) and to manage them as a part of all the other aspects of infrastructures in the city. All the system components have different interactions between them, and all these must be considered by the managers. Water Management is a part of a big metabolism in the city.

Water is involved in many of the aspects of the urban development. As it can be observed in Figure 4.3.3, according to Flemming (2008), water management is a paramount aspect in urban environmental flows. Water is in the centre of population growth in cities, and interacts with energy production by means of hydropower plants, therefore with industry and then communications and land and urban development. There is a competition in urban environments about the water uses: between agricultural productions, and urban uses of water. Among all these aspects, the climate change is a determinant aspect to be considered, in urban environment the impacts of greenhouse gas emissions are more extreme, and water scarcity is more accused when cities are river-dependent. The impact of climate change, related to water cycle affects the social stability, determining the development of cities and the risk of resource scarcities or wealth inequity. These phenomena are local, but nowadays, globalization changes the scale of the problems, affecting even social health and safety. Social development will affect to natural ecosystems, deeply dependent on water. The ongoing degradation and consumption of natural surface waters of rivers, can change the potential equilibrium of the natural ecosystems in which rivers and urban cities are immerse and also this will affect to the climate change. The problem is cyclic and strongly interrelated.

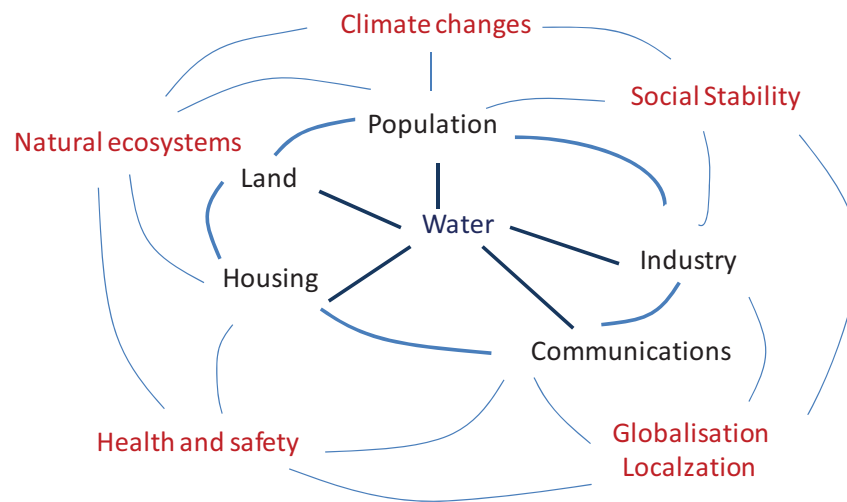


Figure 4.3.3 Interactions in the urban water system.

3 Urban Green Infrastructure and surface waters management

Nowadays, sustainable urban planning is directly related to Green Infrastructure. Water is, of course, part of this. Green Infrastructures can be defined as “a network of decentralized storm water practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain when it falls, thus reducing storm water runoff and improving the health of surrounding waterways” (Center for Neighborhood Technology, 2010), and “more often related to environmental and sustainability goals that cities are trying to achieve through a mix of natural approaches” (Foster et al., 2011).

Thus, the interaction between green-space planning and protection and water management takes paramount importance when surface waters are part of water supply in a city for direct or reuse aspects. This is particularly important in cities crossed by a river, where the river equilibrium is crucial for the water management cycle.

Taking sustainable profit of runoff waters using green infrastructures is an option of adapting cities to the predicted effect of climate change. The use of these infrastructures interacts with savings in river waters, takes pressure off in the city drainage system and reduces the risk of sewer flooding. The most important Green Infrastructures related to water management are: urban trees, permeable pavements, water harvesting, green roofs and other techniques, such as passive irrigation, constructed wetlands, and other.

The potential benefits in urban water management derived from using Green Infrastructure are summarized in Table 4.3.1, adapted from Wise et al (2010).

Table 4.3.1 Benefits of different Green Infrastructure strategies for urban water management.

Measures and benefits from Green Infrastructure	
Urban trees	Storm water detention
	Reducing energy from heating and cooling in urban areas
	Reduce health impacts from extreme heat events
	Air quality improvement in urban areas
	CO2 reduction
Permeable pavements	Increase storm-water retention
	Reduce energy use, air pollution and greenhouse gas emissions
	Reduced ground conductivity
	Reduce air pollution
	Reduce noise pollution
Water harvesting	Reduce potable water use
	Increasing available water supply
	Improved biodiversity
	Public education
Green roofs	Storm water retention
	Reduced building energy use
	Carbon sequestration
	Greenhouse gas emission reduction
	Urban heat island mitigation
	Improve air quality
	Noise reduction
Other infiltration practices: gardens, bioswales, constructed wetlands	Biodiversity and habitat increasing
	Longer roof life
	Storm-water retention and pollutant removal

Nevertheless, the precise quantification across sustainable indicators in urban water management of the hydrological performance of these Infrastructures is more problematic than for engineered Systems. This is due than the specification and control of flow rates, volumes and quality conditions is something but an art for certain types of Green Infrastructures and it is further complicated to compile in the catchment indicators.

For this reason, the consideration of Green Infrastructures in surface water management is an increasing technique. Behind the philosophy of considering Green Infrastructures as water recovering system there is the tripartite consideration of quantity, quality and biodiversity sustainable aspects. Water must be considered integrally with other functions of a city and should also be considered in the water management indicators in order to quantify the benefits derived from this use and add value to the city.

In Table 4.3.2 (adapted from Ashley et al, 2011), a summary is presented about the potential role of GI related to water management in cities and some indicators of how this can improve the overall system.

Table 4.3.2 The potential role of Green Infrastructures in the urban water system.

Issue	Adaptation needs	Indicators of improvement.
Flooding	Managing surface runoff	Faster runoff of surface water. Higher volumes of runoff The increase of green areas will reduce the rate at which rainwater runs and increase the infiltration to better manage intra-urban flood risks
	Managing overland pathways.	Green Infrastructure can provide water storage and retention areas, reducing and slowing down peak flows, and thereby helping to alleviate flooding from rivers and urban watercourses
	Rivers: fluvial waters	
Droughts	Maintaining water quantity	Green Infrastructures can provide a permeable surface which helps to sustain infiltration from aquifers, recharge groundwaters and maintain flow base in rivers
	Maintaining water quality	Green Infrastructures catches sediment and remove other pollutants from the surface waters, improving the overall water quality.
	Maintaining the source	Green Infrastructures can assist with the provision and management of healthy and biodiverse catchments as a whole: reducing the stress on flora and fauna in the urban environment.
Heat	Managing high temperatures	Urban areas are at increasing risk of heat waves due to urban heat island. This occurs because materials used in cities store heat and release it slowly during night, keeping temperatures higher than in rural areas. The effect of evapo-transpiration of Green Infrastructure will improve this phenomenon.
	Providing recreation	The consequences are positives on microclimatic conditions on cities, than can improve the recreation services and water uses of rivers.

4 Parameters used for river waters quality indicators

It is important to relate the traditional conceptualization of the water quality with a more wide term of sustainability indicator proposals. For many years, a limited number of key measures have been used to judge how systems are performing, i.e. in economy: level of employment, rate of inflation, balance of payments, public sector borrowing, etc. These key numbers are Indicators of how well (or bad) the system is doing. Indicators are then quantified information which help us to explain how things are behaving. The variation of these indicators along time will inform modellers about how the key parameters of the system are changing. This information will give an overall picture of the performance of the system, but they must be quantified and compared to standard in order to assess the whole performance. Reliable indicators will alert the modeller about a problem before it gets too bad and they help managers to recognize what needs to be done to fix the problem.

In terms of sustainability, indicators are mainly related to natural resources; and they involve quite complicated assessment. Air quality, water quality and materials used for production have an effect on health and also on economics profits: if a process requires clean water as an input, previous water depuration is an extra expense, which reduces profits; and involves energy incomes and can have health consequences if it fails. Thus, sustainability requires this type of integrated view of the world: multidimensional indicators will be defined linking a community's economy, environment, and society. Also, sustainability indicators have basic functions of: simplification, quantification, and communication. All these functions must be represented in simple expressions. This is a difficult task, especially when dealing with urban waters, in which many agents are implicated.

Inside a wide urban water management concept, cities crossed by a river have particular management strategies. Water management is equivalent to managing conflicts between humans and the environment in the urban environment. A water management system and its catchment are created to avoid such conflicts, to prevent and to solve them. Managers must learn to live with these conflicts and properly address them, knowing well that the relative scarcity of water, the results of economic growth, social demands and climate change affect final equilibrium, as previously stated.

In basins with people or supplying urban areas (particularly those occupied by large populations) these conflicts are more important. These basins are sometimes denominated in a simplified way as "urban watersheds" and in this case, particular indicators of sustainable interactions in the whole systems are here depicted.

Particularly, sustainability indicators for river water quality modelling in urban areas will be related to sustain and improve water quality and the aquatic urban environment. Other aspects observed will be the management of the discharge of waste water, the instruments to control pollution, to ensure adequate water resources of sufficient quality available for abstraction for treatment as drinking water, and the elements which facilitate the recreational use of water where appropriate in the city.

The only way to quantify these key aspects includes chemical and biological ratios of freshwater quality: concentrations of important pollutants, water pollution incidents, and expenditure on water supply and treatment. A list of indicators that could be proposed in this sense is (Gualtieri and López, 2012):

- Dissolved Oxygen (mg/L);
- Biological Oxygen Demand (mg/m³);
- Chemical Oxygen Demand (mg/m³);
- Ammonia – Nitrite – Nitrate concentration (mg/L);
- Phosphorous – Nutrients (mg/L);
- Pesticides (mg/m³);
- Metals (mg/m³);
- Algae presence (mg/m³);
- Pollution incidents (Number of incidents/year/inhabitants);
- Expenditure on water treated in cities for reuse and Amount of treated water for reuses (Cost/inhabitant or m³/inhabitant);
- Expenditure on sewage treatment, Amount of sewage water, and Water treated per inhabitant (Cost/inhabitant or m³/inhabitant);
- Presence of marine outfall. Wastewater thrown to the sea (m³/inhabitant);
- Energy used in pumping/treating water in the city (Kw/m³/inhabitant);
- Rate of drinking water supplied/waste water treated (m³/m³).

5 Tools for determining these parameters: environmental Fluid Mechanic Models

Environmental Fluid Mechanics (EFM) is the scientific study of naturally occurring fluid flows of air and water on our planet Earth, especially of those flows that affect the environmental quality of air and water (Cushman-Roisin et al., 2012), with scales of relevance, which are ranged (i) spatially from millimetres to kilometres, and (ii) temporally from seconds to years. So the EFM must be distinguished from both classical fluid mechanics and hydraulics. Moreover, EFM is aimed at prediction and decision. Indeed, typical problems in EFM concern the prediction of environmental-quality parameters on different scales ranged from (i) short to long term (temporal) and (ii) small to large (spatial) that depend on natural fluid flows, such as bedload transports, pollution levels and climate change. So EFM deals with several different and complex processes, that are basically transport and transformation processes, such as advection, molecular and turbulent diffusion, and physical, chemical and biological transformation phenomena.

In water systems, the study of the above EFM processes is aimed to gain a better knowledge about how the introduction of pollutants of different kind and nature in a water body will produce the ultimate levels of quality in the aquatic environment. In fact, in developed countries, the main problem of water management is the incompatibility between the average water quality, on the one hand, and the needs for ecosystem protection and the desirable water use or uses (i.e. recreation, water supply, agriculture, etc.), on the other hand. To achieve qualitative levels compatible with these two objectives, engineering controls are devised; such water quality criteria are often expressed by acceptable values of the parameters which represent health condition for the ecosystem. This is also taken into account in European and National legislations.

The EC-Water Framework Directive (WFD 2000, 2008) has the objective of an integrated catchment-oriented water quality protection for all European waters with the purpose of attaining a good quality status by the year 2015. The water quality evaluation for surface waters shall rely mainly on biological parameters (such as flora and fauna) – however, aided by hydro-morphological (such as flow and substrate conditions) and physico-chemical quality components (such as temperature, dissolved oxygen or nutrient conditions) – and on specific pollutants (such as metals or synthetic organic compounds). A good chemical quality status is provided when the environmental quality standards are met for all pollutants or pollutant groups. A significant aspect of the EC water policy is the combined approach, i.e. both limitations on pollutant releases at the source due to promulgation of emission limit values (ELVs) as well as the establishment of environmental quality standards (EQSs). Releases of pollutants, especially from point sources, must meet both requirements. For most European member countries this policy introduced a considerable deviation from current water quality management practice by which the releases of pollutants has been controlled by either one of these two control mechanisms, but usually not their combination. The issue of ELVs and, especially, EQSs in natural water systems could be easily related to the concept of sustainability. This concept is at the core of the water management model that the WFD puts forward.

6 Conclusions

Section IV-3 has presented a review of the interactions and flows in the urban water management system, with particular consideration for urban watercourses. Rivers play a crucial role in many aspects of urban development: economic, governance, recreational, health among others, and to understand their performance and sustainability via appropriate indicators is crucial.

Green Infrastructure is essential deliver sustainable urban management strategies. The aspects of Green Infrastructure related to surface waters have been also presented in Section IV-3. Finally, a particular set of sustainability indicators focused on river water quality are presented. These parameters must be evaluated by means of modellers: Environmental Fluid Mechanics Models are also introduced as a powerful tool for monitoring the sustainable implications of the river system.

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Section IV-4

Evidence on the contribution of green urban infrastructure to climate change mitigation and adaptation

Matthias Demuzere¹, Maija Faehnle², Kati Orru³, Eduardo Olazabal⁴, Davide Geneletti⁵, Oliver Heidrich⁶, Hans Orru⁷, Efren Feilu⁴, Ajay G. Bhawe⁸ and Neha Mittal⁸

¹ KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium

² Finnish Environment Institute (SYKE), Helsinki, Finland

³ Institute for Agriculture and Environment, Estonian University of Life Sciences, Tartu, Estonia

⁴ Energy and Environment Division, Tecnalia, Derio, Spain

⁵ University of Trento, Department of Civil, Environmental and Mechanical Engineering, Trento, Italy

⁶ School of Civil Engineering and Geosciences, Newcastle University

⁷ University Tartu, Department of Public Health, Tartu, Estonia

⁸ Indian Institute of Technology Kharagpur, India

Highlights

- This paper is reporting on the positive contributions GUI (Green Urban Infrastructure) can make to climate change (CC) mitigation and adaptation efforts in cities.
- The influence of GUI is investigated on both physical and psychological and social benefits using empirical evidence published in the literature.
- Outcomes from an increased number of empirical studies can be used to improve the planning and designing of GUI in order to lower the vulnerability of urban areas to CC effects such as flooding and heat islands.
- We provide a framework of GUI services and benefits and outline that defining the scales of benefits (spatial scales and individual, political and policy-making scale) carries several practical advantages.
- We show the relevance of the benefits from GUI on three spatial scales (i.e. city, neighbourhood and site) and discuss the co-benefits and trade-offs caused by GUI.
- A range of domains are in need of further research, such as CO₂ storage and sequestration and cooling of building-integrated greenery, the impact on thermal comfort for the wider urban area, absorption of air pollutants according to species and the cumulative effect of GUI on runoff, groundwater recharge, evapotranspiration and stormwater quality.

1 Introduction

Urban areas are facing increasing challenges related to climate change (CC), from floods and droughts to issues of human comfort and environmental justice (Rosenzweig et al., 2011). In responding to these, several opportunities arise from conscious planning and design of green (and blue) spaces in urban landscapes. In recent years, the potential role of green infrastructures to respond to CC has gained interest and popularity.

The concept of green infrastructure was first introduced in the USA at the end of 1990's primarily aiming at the protection of natural systems from disturbances by urbanization (Benedict and McMahon, 2006). Green infrastructure has also been interpreted as a fine-scale urban application where hybrid infrastructures of green spaces and built systems are planned and designed to support multiple ecosystem services (Pauleit et al., 2011). In recent European definitions, green urban infrastructure (GUI) refers to vegetated areas and elements such as meadows, forests, wetlands, shores, parks, green roofs and walls, trees etc. that together contribute to ecosystem resilience and human benefits through ecosystem services (EEA, 2012; Naumann et al., 2011). GUI has been approached in several ways. One approach is based on the ecological network concept and focuses on the protection of ecosystems and its services (Benedict and McMahon, 2006; Hostetler et al., 2011; Ignatieva et al., 2011). Water-related aspects of GUI have been studied with an hydrological approach which refers to sustainable water management in different scales from landscape to site (Ahern, 2007; Dietz, 2007; Pyke, 2011). In turn, an integrated approach highlights the need for an integration of functions from nature conservation to social benefits for citizens from regional to local (neighbourhood) scales (Madureira et al., 2011; Niemelä et al., 2010; Naumann et al., 2011; Pauleit et al., 2011).

In scientific debates on climate change mitigation and adaptation, GUI has often been described in terms of policy and governance but less in terms of an holistic analysis on empirical evidence for benefits or disadvantages of the suggested measures. The assessment of the potential of ecosystem-based approaches to CC adaptation and mitigation in Europe (Naumann et al., 2011), for example, focuses on strategies, implementation recommendations etc. on different policy levels and in terms of regulations. Contribution of GUI to CC mitigation and adaptation services and benefits has been studied in terms of specific services and benefits (e.g. Gill et al., 2007; Laforteza et al., 2009; Foster et al., 2011), and conceptual frameworks have been developed for addressing services and benefits in multi-scalar contexts (e.g. Cash et al., 2006; Cook et al., 2012; Scholes et al., 2013). However, to our knowledge, there are no comprehensive studies summarizing the evidence on the contributions of GUI to CC mitigation and adaptation.

Section IV-4 explores the existing empirical evidence about the contribution of GUI to CC mitigation and adaptation services and benefits, as support for planning, management and design of urban areas. To this purpose, we identify a set of GUI services and benefits that are essential for CC mitigation and adaptation, and review the available empirical evidence. Building on this, issues related to the spatial scales for addressing production of the services and benefits and potential co-benefits and trade-offs are addressed. Finally, knowledge gaps are identified.

2 Evidence on services and benefits provided by GUI

In order to draw together the empirical evidence on the contribution of GUI from a CC mitigation and adaptation perspective, we adopt the framework of ecosystem services that are relevant for the provision of these benefits. Ecosystem services can be defined as the contribution of ecosystems to human well-being, based on ecological phenomena (Fisher et al., 2009). Services are the production of benefits that are of value to the people (Chan et al., 2012). For example, carbon storage and sequestration (service) contributes to decreased CO₂ emissions (benefit), and regulation of climate (service) contributes to human thermal comfort (benefit) (Figure 4.41). Each of these services arises from biophysical processes and functions, including e.g. gas cycles for carbon storage and sequestration and evapotranspiration by vegetation for micro-climate regulation. In addition, also the human agency plays an important role in shaping service provision, especially in an urban

context. By establishing and maintaining plantations in a park people affect the services the park provides, e.g. micro-climate regulation and air purification.

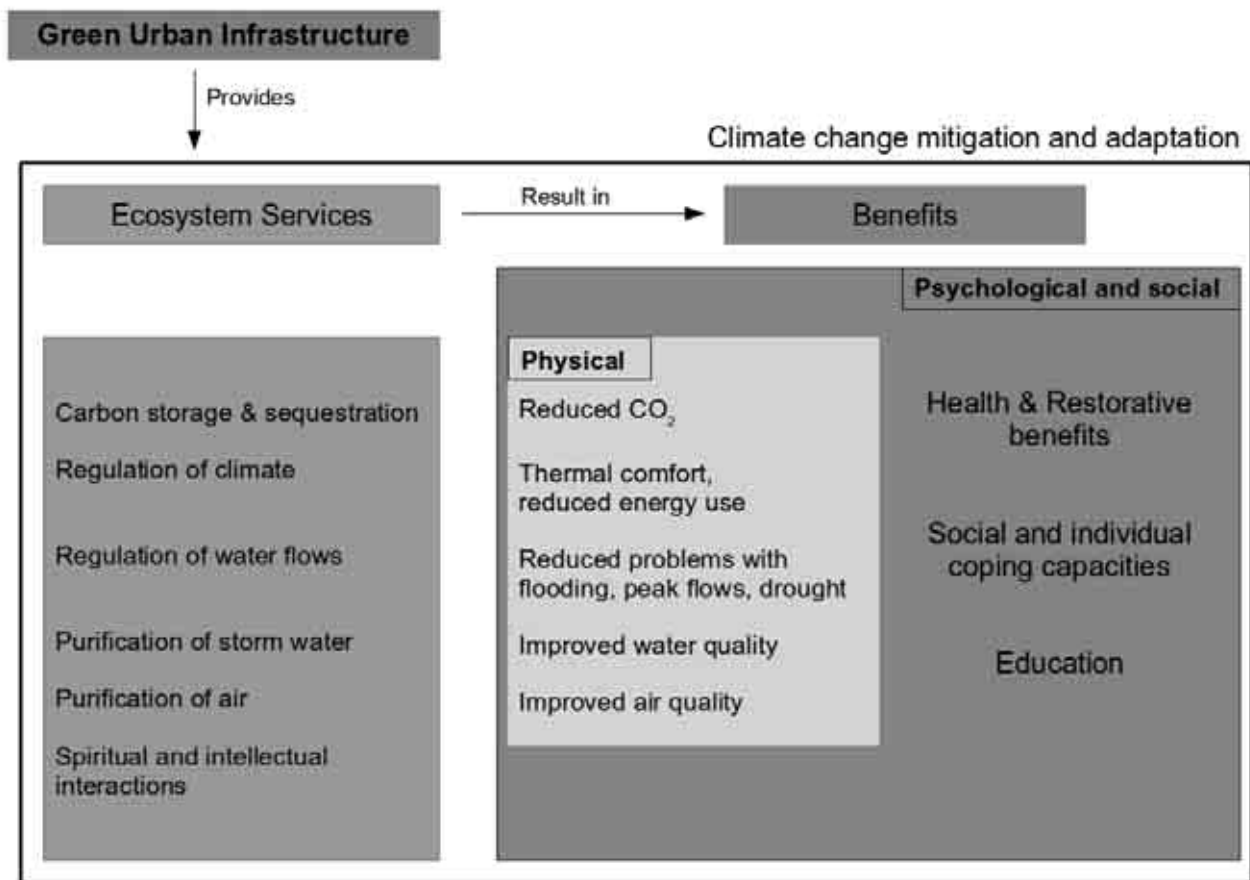


Figure 4.4.1 Green urban infrastructure services and benefits within a climate change mitigation and adaptation framework. It's not clear how these keywords were assembled, and what all of them entail (e.g., spiritual and intellectual interactions, coping capacities, restorative benefits etc.).

In the following, empirical evidence on the role of GUI in the context of CC mitigation and adaptation is discussed according to the physical and psychological/social benefits categories as depicted in Figure 4.4.1. For some GUI services and benefits, insights from modelling studies - e.g. improved air quality issues or services on the city-scale - have been included in order to further clarify the potential role of GUI as CC mitigation and adaptation strategy. Categorization of services and benefits is of course complicated because of the multi-scalar and multi-functional nature of GUI and the multiplicity of interactions between the various phenomena listed above. For example, thermal comfort and improved air quality (physical benefits) contribute to human health and quality of life (health and restorative benefits), but the latter also depend on many other issues. An aesthetically pleasant floodplain provides flood protection by regulating water flows (service), enable recreation (health and restorative benefit), but may also offer a site for gaining practical knowledge on the importance of the floodplain in climate change adaptation (educational benefit). There are overlaps between the services and benefits, and the list brought out and discussed here is not exhaustive (e.g. food security benefits of urban agriculture are excluded). However, based on the evidence from existing literature, we have categorized the key services and benefits that reflect the role of GUI in the context of CC mitigation and adaptation.

2.1 Physical benefits

2.1.1 CO₂ reduction

GUI removes CO₂ from the atmosphere via photosynthetic uptake during the day and releases CO₂ at night via respiration, while additional uptake can occur via below-ground biomass and soils (Velasco & Roth, 2010). The relative strength of all source and sink terms will eventually make up the net urban CO₂ flux. Until today, the understanding of how different processes (e.g. photosynthesis, respiration, fossil fuel combustion) interact lags behind, resulting in a poor knowledge on the magnitude of vegetation carbon sources and sinks in urban areas, as well as on their seasonal dynamics, spatial patterns and the role of different plant types and their physiology in different types of cities and climates (McFadden, 2012).

A number of studies quantified the potential of city-wide urban green (generally referring to all aboveground live biomass) as a carbon sink following a bottom-up strategy. In a first step, the urban area of interest is more precisely delineated and land cover characteristics are determined via geographical information systems. A vegetation survey is performed for randomly chosen quadrants within each land cover class in order to identify types of vegetation (herbaceous vegetation, cultivated, bare soil, trees, woody vegetation, etc.) and in the case of trees, species or genus, diameter at breast height, crown height and canopy cover. Afterwards above-ground dry-weight biomass is generally calculated using species-specific allometric equations provided by e.g. Zianis et al. (2005) and Snorrason and Einarsson (2006). Carbon sequestration rates are sometimes also provided and can be derived as a function of a standardized growth rate and a difference in carbon storage between year x and year $x+1$ (Nowak et al., 2013).

Jo (2002) assessed the impact of urban green space for three cities in South Korea. According to his estimates for above-ground biomass, storage for woody plants ranges from 26 to 60 t C ha⁻¹ for natural lands and between 4.7 to 7.2 t C ha⁻¹ for urban lands. Carbon sequestration rates ranged from 1.6 to 3.91 t C ha⁻¹ yr⁻¹ for natural lands within cities and 0.53 to 0.8 t C ha⁻¹ yr⁻¹ for urban lands. In Europe, Davies et al. (2011) examined the quantities and spatial patterns of above-ground carbon stored in Leicester (United Kingdom), by surveying vegetation across the entire urban area. Based on the species total surface fraction across the entire urban area of Leicester a total average carbon budget storage of 31.6 t C ha⁻¹ was calculated. Domestic gardens alone were reported to store 7.6 t C ha⁻¹ which is not significantly different from herbaceous vegetation land cover (1.4 t C ha⁻¹). Hutyra et al. (2011) characterized above-ground terrestrial carbon stocks along three sample transects radiating away from the Seattle (USA) central urban core. These transects were divided in three parts, and for each of the five defined urban classes (based on the percentage impervious surface), approximately thirty samples are obtained. They report a 18 +/- 13.7 tonnes of C storage per hectare within the urban land covers of the Seattle (USA) urbanized region. A similar approach was followed by Zhou et al. (2010) as they report carbon offsetting of urban forests in Hangzhou (China). The average carbon storage and sequestration rate in the Hangzhou downtown area was estimated at 30.25 t C ha⁻¹ and 1.66 t C ha⁻¹ yr⁻¹ which suggest that urban forestry planning and management in China could be a method to mitigate climate change second only to the development of alternative energy sources. Raciti et al. (2012) derived a carbon storage of 72 +/- 4 t C ha⁻¹ for the Massachusetts portion of the Boston metropolitan statistical area (USA). These estimates were based on a land cover characterized by 41.7% forest, 25.6% residential and 10.2% other developed areas. More recently, Nowak et al. (2013) report a variable carbon storage per hectare of urban tree cover between 31.4 t for South Dakota (USA) and 141.4 t for Omaha

(Nebraska, USA) with an overall carbon storage of $76.9 \text{ kg C ha}^{-1}$ averaged over all 28 cities in six states. The net carbon sequestration rate per hectare of tree cover averaged over all sampled cities and states was estimated at $2.05 \text{ t C ha}^{-1} \text{ yr}^{-1}$.

Although these numbers reveal a CC mitigation potential for GUI in offsetting urban carbon emissions, it remains difficult to provide more generalized unambiguous conclusions. For example, the applied allocation rules and threshold values such as the tree diameter at breast height vary greatly amongst the studies and different correction factors are used to account for an overestimation of the allometric equations which are almost exclusively derived for natural trees (Nowak, 1994). Perhaps more important is the lack of consistency in defining urban areas (Raciti et al., 2012). Differences in carbon stock using e.g. the U.S. Census Bureau's urban areas based on population density and the GRUMP (Global Rural–Urban Mapping Project) urban area based on global night-time lights data can to a large extent alter the evidence about the importance of urban soils and vegetation in regional carbon budgets (Raciti et al., 2012). In addition, other limitations remain as well. Only few of the studies take into account urban carbon storage by below-ground biomass and urban soils and they generally do not consider a full life cycle assessment (LCA) that takes into account e.g. transportation and maintenance activities such as pruning, removals, irrigation and fertilization.

With respect to urban soils, the review by Pataki et al. (2006) lists a number of studies revealing an in- or decrease in carbon in urban and native soils depending on climate conditions (warm/dry versus cold/wet), land cover type (e.g. golf course versus dredge sites) and soil type. Washbourne et al. (2012) studied carbonate formation across a 10 ha brown-field at the Science Centre in the centre of Newcastle upon Tyne (U.K.) and showed that, for a soil volume of 1×10^6 tonnes characterized by Ca-/Mg-rich silicate minerals, a total carbon capture potential of $17 \times 10^3 \text{ t C}$ could be achieved. This adds weights to the idea that engineered soils (together with a progressive urban planning and green infrastructure development) could be effectively utilized for carbon capture and storage. With respect to LCA, only Strohbach et al. (2012) provide a full assessment that applies a carbon footprint analysis to urban green space that includes ecological and technological components. Based on different design and management scenarios they conclude that carbon sequestration can be much larger than emissions from construction and maintenance, by minimizing the use of motorized machinery and keeping tree mortality low.

Nordbo et al. (2012) present a different approach: a top-down strategy describing the concept of Net Urban Ecosystem exchange (NUE). This concept describes the CO_2 budget of the measured CO_2 reflecting urban background activities including local emissions from e.g. transport and buildings but excluding strong sources such as power stations often located outside of the cities' boundaries. Firstly they derive the natural fraction (fn) from the urban land cover which is defined as areas dominated by built environment including all non-vegetative, human-constructed elements like buildings, roads, and runways. Secondly, the natural fraction is fitted to observed CO_2 fluxes from eddy-covariance towers for different urban areas in different continents. The technique is based on measuring simultaneous turbulent variations in wind and gas concentrations (e.g. CO_2) and the measurements are representative over several hectares depending on measurement height and upwind surface and flow properties. Their non-linear fit can be described by $\text{NUE} = -12 \text{ t C ha}^{-1} \text{ yr}^{-1} + 6.2 \text{ t C ha}^{-1} \text{ yr}^{-1} \exp[2.8(1-\text{fn})]$ suggesting that urban areas are a net sink of CO_2 if their natural fraction exceeds about 80%. This large number reveals an important issue when it comes to using green urban infrastructure projects for carbon mitigation: space in cities is limited and thus more

alternative approaches such as building-integrated GUI (green façades, roofs etc.) could gain more importance in the future.

Unfortunately a comprehensive literature search on empirical evidence of potential CO₂ storage and sequestration from building-integrated GUI did not yield much results. Only Ismail et al. (2012) reports measuring daily CO₂ uptake for ten pots of *Ipomoea-pes-caprae* (beach morning glory). Photosynthesis rates were measured with a LI-6400 portable photosynthesis system for selective periods in July 2009 and April 2010 and from these two short periods, the annual net photosynthesis rate was estimated at 2.3 t C ha⁻¹ yr⁻¹. This short-list stresses future research needs with respect to green urban infrastructure at local to neighbourhood scales in order to improve our understanding of carbon storage and sequestration capacities of various vegetation types, for various climate zones and at different urban scales.

2.1.2 Thermal comfort and reduced energy use

The physical properties of GUI play a role in reducing air and surface temperature by providing shading and by enhancing evapotranspiration, which contributes to the removal of latent heat from soil. Hence, GUI can play a role in climate change adaptation by serving as a climate regulator leading to two benefits that are highly interrelated: reduced energy use and improved thermal comfort. With respect to the latter, a large number of studies have identified a wide range of other variables that also influence (human) thermal comfort, such as e.g. wind speed, radiation, globe temperature, ground surface temperature, mean radiant temperature, anthropogenic heat, relative humidity, evaporation and evapotranspiration of plants, ground surface covering, shading by trees and man-made objects (Xi et al. 2012; Johansson and Yahia, 2012; White et al. 2012; Lin et al. 2012; Coutts et al., 2013). Based on these variables, comfort indices are designed to quantify the outdoor thermal environment (highly related to the human thermal comfort) such as e.g. Physiologically Equivalent Temperature Index (Lin et al. 2012), Predicted Mean Vote (Lenzholzer, 2012) or more recently the Universal Thermal Climate Index (McGregor, 2012). While we acknowledge the usefulness of such indices, the thermal comfort and reduced energy benefits via more direct observed physical indicators such as ambient temperature, turbulent fluxes and energy savings are considered here. This is done for various types of GUI, such as planting trees and improving green areas, and applying green roofs or green façades on buildings.

Bowler et al. (2010) presented a systematic review of the available evidence on the effects of greening on the air temperature of urban areas. Their meta-analysis suggested that, generally, an urban park would be around 1°C cooler than a non-green site. However, the authors also concluded that the impact of specific greening interventions on the wider urban area, and whether the effects are due to greening alone, has yet to be demonstrated. Gill et al. (2007) suggested that increasing the current area of green infrastructure in Greater Manchester by 10% (in areas with little or no green cover) could result in a cooling of up to 2.5 °C under the high emissions scenarios based on the UK Climate Impacts Programme (UKCIP02) predictions by the 2080's. Parks in Taipei of at least 3 ha have been shown to be cooler than their surrounding urban areas while the temperature in parks of less than 3 ha is more variable, and the quantity of paved surfaces in a park also causes variation in park temperatures (Chang et al., 2007). Studies of parks in Singapore Yu and Hien (2006) showed that the temperature outside the park's boundary gradually increases when moving further away from the green area, suggesting that the park has a cooling effect and that this extends beyond the boundary. The largest of the parks (156 ha) showed the strongest relationship between temperature and distance.

Yu and Hien (2007) studied the thermal benefits of a city's natural reserve and a neighbourhood park in Singapore, revealing that the cooling impact of the parks are reflected not only through lower temperatures in the parks, but also through lower temperatures in the surrounding built environment (maximal average temperature difference in locations nearby the park: 1.3 °C). A simulation of cooling energy load in surrounding buildings was then conducted, observing a maximum 10% reduction of energy consumption. Similar conclusions, on a smaller scale, are drawn by Shashua-Bar and Hoffman (2000). These authors predicted the cooling effects of small urban green wooded sites in Tel Aviv, by performing statistical analysis on experimental data collected at 11 sites. The average cooling effect in all sites was about 2.8 °C, and it was perceivable up to about 100 m in the streets branching out from the site.

As shown in the review by Cameron et al. (2012), also domestic gardens play a significant role in climate mitigation, in particular by insulating houses against temperature extremes (which leads to reduced domestic energy use), and improving air cooling locally. Shashua-Bar et al. (2009) compared the efficiency of urban landscape strategies for outdoor cooling in hot dry climate, and concluded that courtyards treated with shade trees and grass yielded a daytime temperature depression of up to 2.5 °C. Also green roofs have received increasing attention in the literature with respect to improving thermal comfort. In general, green roofs often reflect more sunlight than conventional rooftops (Santamouris, 2012), improve rooftop insulation, cool the air via evapotranspiration from plants and evaporation from soils and reduce energy demands/costs via cooling and insulation (Cook-Patton and Bauerle, 2012). However, their capacity to cool the environment can be limited, especially in high rise buildings (Armson et al., 2012). In their systematic empirical review on urban greening for various sites around the globe, Bowler et al. (2010) conclude that surface temperatures of green roofs are cooler than non-green roofs, even though the actual difference changes according to the time of the day and the season. Moreover, effects also vary depending on the geographical region, the climatic conditions and seasonal weather and volume of water that has been stored in the system. For example during summer - when temperatures are high - poor protected roofs will result in overheating of spaces found beneath them which will unavoidably lead to an increased need of mechanical cooling and hence energy consumption (Jaffal et al., 2012).

A review by Castleton et al. (2010) concluded that green roofs can significantly reduce energy use (both in summer cooling and winter heating) in buildings with poor insulation systems. However, their effect is much more limited in modern buildings with better roof insulation. The City of Toronto has estimated that the direct energy savings citywide, through reduced energy for cooling as a consequence of whole scale greening would be in the order \$22 million, equivalent to 4.15kWh/m² per year [CO₂ emission saving of 1.7kg/m²]. There would also be a reduction in peak demand in the order of 114.6MW leading to fossil fuel reductions in the region of 56,300 metric tonnes per year (www.toronto.ca/greenroofs/index.htm). A study conducted by Nottingham Trent University compared two kinds of rooftops, one green roof and one normal roof, under a mean daily temperature of 18.4 °C. Findings of the research have clearly illustrated that the temperature beneath the membrane of the normal roof was 32 °C while for the green roof it was only 17.1 °C. A similar study in Chicago estimates that if all the rooftops of the city had green roof systems on each building savings across the city could be in the region of \$100.000.000 per year due to reduced demand for air conditioning (<http://www.livingroofs.org/energcons>)

Green roofs can also become very important during the winter since they can assist with the insulation of the roof by reducing heat loss from building. In this respect, the presence and amount of water being stored within the substrate will determine how efficient thermal performance will be. For example, in the U.K., where the climate is wet, thermal performance of the roof is expected to have fewer benefits when having green roofs. A study at Trent University (trent.ac.uk) showed that a green roof had a positive effect compared to a normal roof during winter when the following conditions occurred: mean temperature was 0 °C; temperature under membrane of the standard roof was 0.2 °C; temperature under the membrane of the green roof was 4.7 °C. Thus some heat is retained.

Coutts et al. (2013) compared 4 experimental roofs: a conventional steel sheet roof, a steel sheet roof covered with white, high albedo paint, a vegetated roof and a roof with just the soil layer over the summer of 2011-2012 in Melbourne, Australia. Their results suggest that cool roofs, if combined with insulation, would probably provide the greatest overall benefit in terms of urban heat mitigation and energy transfer into buildings. The high albedo of the cool roof substantially reduced net radiation, leaving less energy available at the surface for sensible heating during the day. Under warm and sunny conditions when soil moisture was limited, evapotranspiration from the green roof was low, leading to high sensible heat fluxes during the day. Irrigation improved the performance of the green roof by increasing evapotranspiration. Thus they conclude that rooftops must be designed accordingly to target specific performance objectives, such as heat mitigation. Another comparative study of concrete and green roofs and walls across 9 cities in the world, Alexandri and Jones (2008) found that the concrete roof 24h profile ranges from 345.1 to 128.6W/m², while for the green roof's upper surface; it only ranges from 51.3 to 99.9W/m². It became evident that, the hotter and drier the climate, the more important the effect of green walls and green roofs on mitigating urban temperatures. They concluded that if such measures are applied across the city raising temperatures can be mitigated and energy saving for cooling buildings from 32% to 100% can be achieved.

Concerning green façades, Cameron et al. (2012) claim that robust data about the mitigation effects are still lacking, even though the work by Cheng et al. (2010) concluded that the application of turf as vertical greening reduced the interior surface temperatures by more than 2 °C. Ottel   et al. (2011) presented a life-cycle analysis of a conventional built up European brick façade, a façade greened directly, a façade greened indirectly (supported by a steel mesh), a façade covered with a living wall system based on planter boxes and a façade covered with a living wall system based on felt layers. They concluded that all of the above greening systems are the environmentally preferable choice when constructing or retrofitting a building due to their reduction in energy demand for heating and cooling, even though the initial additional resources can have a high environmental burden. However, they also state that further research is essential for improving the analysis to confirm or refute the assumptions made in this study, especially for the unquantifiable categories such as increased biodiversity, human health, improvement of air quality and mitigation of the urban heat island effect.

2.1.3 Reduced problems with flooding, peak flows and drought

Due to alteration in spatio-temporal characteristics of hydrologic processes in urban landscapes, hydrological systems are losing their buffering capacity, thereby, aggravating the risk of flooding. Increase in impervious surfaces and changing urban land use, such as reclamation of wetlands for development, will exacerbate the adverse impacts of climate change (Parry et al., 2007). Forests,

wetlands and floodplains are known buffers of peak flows and also water purification. These services are of urgent relevance for urban areas for adapting to changing weather patterns and changing dynamics of human requirements (Farrugia et al., 2013). Studies have shown that climate change may cause local-scale intense precipitation events, which in urban areas can lead to damaging floods (Bates et al., 2008).

Jones et al. (2012) have made a compelling case for mitigating the impacts of climate change through ecosystem-based adaptation measures which target specific ecosystem services in the face of uncertain evolution of future needs. Vegetation provides vital ecosystem services by reducing runoff and facilitating greater deep percolation through the process of precipitation interception and by enhancing interflow in the underlying soil (Farrugia et al., 2013). Changing vegetation cover influences water yield, floods, low flows, sediment yield and sediment chemistry, while impervious surfaces modify water flow paths, increase overland flow towards receiving water bodies such as streams (National Research Council of the National Academies, 2008). Urban infrastructure alters the hydrological components and consequently the physical and hydrological characteristics of receiving water bodies. While up to 60% of rainwater contributes to runoff in vegetation-free cities, vegetated areas contribute between 5 – 15%, thereby reducing peak discharge and recharging the groundwater (Bolund and Hunhammar, 1999; Spatari et al., 2011). Studies evaluating the impact of green urban infrastructure on rainfall events in a changing climate show that successful adaptation will need provision of green cover along with hard engineering practices, such as increasing storage. Moreover effective functioning of these urban ecosystems will depend on their location in the urban landscape, and hence should consist of a matrix of corridors and patches in areas with soils having high infiltration capacity (Gill et al., 2007; Ellis, 2013).

Cities in Germany, the Netherlands and Australia have historically been successful in utilizing green urban infrastructure. The Australian Government is funding a 15 year research programme, Cooperative Research Centre for Water Sensitive Cities, with special focus on catchment scale planning and urban design for sustainable urbanism in a changing climate (see e.g. Coutts et al., 2013). The acceptance of such an approach is rising in the US with the US Environmental Protection Agency (EPA) endorsing green infrastructure techniques, especially for stormwater management (Keeley et al., 2013). Recent US EPA cost benefit studies for green infrastructure programmes highlight alternatives that consistently provide more value than hard infrastructural strategies. The City of Portland, Oregon, a leader in implementing green urban infrastructure for reducing the stormwater outflow, has shown that vegetated swales and parking lot infiltration are highly cost efficient (US EPA, 2010). Odefey et al. (2012) report that the incorporation of infiltration trenches and rain gardens in the Arlington-Pascal Stormwater Improvements project reduced runoff volume and alleviated flooding impacts in the highly flood prone urbanized Como Lake catchment. The US EPA (2010) reports that to provide flood protection during peak events, large scale GUI projects, including rain gardens, bio-swales, have been used by Lenexa, Kansas, and Stafford County, Virginia. Along with initiatives by the municipalities, citizen based initiatives have also been reported. The Green Alley Program in Chicago, which used pervious pavement for 3500 acres of alleyways, was based on home-owner complaints. On the other hand, the 10,000 Rain Garden project in Kansas City involved individuals, corporations, civil society and the government to reduce runoff through rain gardens, bio-swales and rain barrels to reduce runoff.

Although on a much smaller scale of 5 acres, implementation of bio-swales and rain gardens at the Episcopal High School, Baton Rouge, Louisiana, has avoided the previously common flooding and

drainage problems. Moreover, this solution was about \$390,000 cheaper than the estimated \$500,000 for the alternative solution of re-piping the ageing drainage system (Odefey et al., 2012). Scientific assessment of bioretention cells have shown a reduction in peak flows of at least 96.5% for small to medium-sized storm events (Hunt et al., 2008). Large cell media volume, drainage area ratio and locally suitable drainage and infiltration configuration further improve the performance of such cells as shown by Li et al. (2009) with regards to six bio-retention cells in Maryland and North Carolina. They conclude that such hydrologic improvements promote groundwater recharge, assist in managing floods and also address channel erosion issues. Comparison of green and black roof plots at the University of Georgia indicates similar effects, where precipitation retention for smaller storms (2.54 cm depth) is greater than for large storms (7.62 cm depth) whilst monitoring of the Chicago City Hall's green roof demonstrates a runoff reduction of 50%. Green roofs also increase runoff lag times by up to 100% meaning that the flood hydrograph would have greater resemblance to pre-development period (Carter and Rasmussen, 2006; US EPA 2010).

Mentens et al. (2006) have reviewed German studies on intensive green roofs over a 16 year period demonstrating a runoff reduction ranging from 65-85%. This reduction, largely due to the temporary retention and evapotranspiration, depends on the structure of the green roof (layers and their depths), climatic conditions and the precipitation amount for a particular storm event. However, because urban rooftops typically comprise about 5-10% of the impervious area, other impervious surfaces such as roads, parking areas, pavements etc. should also be considered. This is especially relevant for high intensity rainfall events, expected to increase in future due to climate change, where green rooftops are less effective.

2.1.4 Improved water quality

Urban areas alter the water quality characteristics of receiving water bodies by transferring contaminants such as sediments, heavy metals, hydrocarbons, pesticides, nutrients, toxic chemicals and micro-organisms. Impervious surfaces such as concrete, pavements and tarmac increase peak flood discharge and degrade water quality by picking up street pollutants. Davis et al. (2009) review shows that besides influencing the quantity and timing of runoff, GUI infrastructure has been found to improve the physico-chemical characteristics of the water by removing suspended solids, nutrients, hydrocarbons, and heavy metals. Pollutant removal mechanisms like filtration, adsorption and biological treatment mechanisms combined with runoff reduction results in reduced pollutant loads. Such a linkage between hydrologic performance and water quality is found in the Arlington-Pascal Stormwater Improvements project where reduction peak flows and runoff volumes were associated with reduction in the Total Phosphorus (TP) and Total Suspended Solids (TSS) (Odefey et al., 2012). A seven year monitoring programme of the artificial wetlands of the Dartnall Road Interchange, Ontario, revealed removal of heavy metals such as Cu, Fe, Pb and Zn from highway runoff, along with TP, TSS, Total Kjeldahl Nitrogen (TKN) and faecal coliforms, through processes such as chemical precipitation, adsorption and biological uptake (Farrell & Scheckenberger, 2003). Similarly Hunt et al. (2008) found that bioretention systems in urban areas can reduce pollutant concentrations, including bacteria, along with attenuation of peak flows.

Davis et al. (2009) summarize several field and laboratory studies evaluating the performance of GUI infrastructure for improving water quality and suggest that bioretention systems may be the best management practice for pollutant removal. However, grass bioretention cells have been found to perform better at faecal coliform removal and nutrient pollution abatement compared to vegetated cells with trees, shrubs and mulch (Passeport et al., 2009), whereas in areas with snow

melt, swales have been proposed as primary treatment mechanisms due to ability to retain pollutants (Backstrom, 2003). Wadzuk et al. (2010) find that constructed stormwater wetlands reduce TSS, Total Dissolved Solids (TDS), total nitrogen, phosphorus, chlorides, heavy metals and *Escherichia coli* of urban stormwater runoff. An experimental study of a parking lot bio-swale found that it reduced the pollution loading by 95.4% compared to the control site (Xiao & McPherson, 2011). A review on the ability of green roofs in reducing phosphorus, nitrogen, heavy metals and pH by Czemieli Berndtsson (2010) reveals that green roofs can potentially benefit the urban environment. The soil material and fertilizers added for the maintenance of the green roof are a major influence on the runoff quality and correspondingly, a majority of studies showing an increase in phosphorus content (Czemieli Berndtsson, 2010; Gregoire and Clausen, 2011). However for most water quality contaminants, modular green roofs, tested by Gregoire and Clausen (2011) have reduced overall pollutant loading by acting as a sink for nitrogen, Pb and Zn. Although, the efficiency of removal depends on the type of pollutant, type of measure used, type of vegetation, soil properties, addition of fertilizers and local climatic characteristics, overall, studies indicate the value of GUI in removing pollutants and improving water quality.

2.1.5 Effects on air quality

GUI offsets air pollution by directly removing pollutants from the air due to dry deposition and absorption, influencing dispersion conditions and reducing (increasing) high temperatures and sunlight (biogenic volatile organic compounds (BVOCs) emissions) that can lead to a weakening (strengthening) of ozone formation. A main function of GUI for improving air quality is the absorption of pollutants like particulate matter (PM). However, there is only limited amount of empirical evidence available and most of the projections use modelling efforts or at least include it in some parts of the analysis. The empirical evidence is mainly related to roadside vegetation. Brantley et al. (2013) have seen reductions in black carbon behind the vegetation barrier (being more efficient during downwind); however, they did not see changes in coarse or fine particle levels. Furthermore, Hagler et al. (2012) noticed the effect of structural barriers on near-road ultra-fine particle concentrations, although for the vegetative barriers the results were variable. Also hedges located directly near the road side may also significantly reduce exposure of pedestrians and cyclists to road traffic emissions (Keuken and Valk, 2010). A study on the effects of urban park or forest vegetation on air quality in two northern cities (Setälä et al., 2013) found vegetation-related environmental variables insignificant for levels of NO₂, anthropogenic VOCs and particle deposition.

Evidence based on modelling studies is much broader. There are several studies available in London, where GUI is estimated to remove 852-2121 tonnes of PM₁₀ annually, which equates to 0.7-1.4% PM₁₀ reduction (Tallis et al., 2011). Tiwary et al. (2009) have found that a 10 × 10 km grid in London with 25% tree cover could remove 90.4 tonnes of PM₁₀ per year, which accounts for 2 avoided deaths and 2 avoided hospital admissions every year. The recent analysis in 10 U.S cities showed that the total amount of PM_{2.5} removed annually by trees varied could be up to 64.5 tonnes in Atlanta with highest positive effect in New York City with eight fewer premature deaths every year (Nowak et al., 2013a). Nevertheless, the absorption of pollutants varies widely depending on the type of vegetation. Freer-Smith et al. (2005) found that Coniferous species are able to capture more particles than species with broad leaves, while among the latter whitebeam (*Sorbus aria*) captured the most and poplar (*Populus* spp.) the least weight of particles. Moreover, the leaves with complex shapes as large circumference-to-area ratios, waxy cuticles or ridged hairy leaves collect particles more efficiently (Tiwary et al., 2009; Mitchell et al., 2010). Also the location of trees

makes a difference in levels of absorption of PM. Trees situated close to a busy road captured significantly more material from the largest particle size fraction than those situated at a rural, background site (Beckett et al., 2000). It has also been demonstrated that green roofs help to reduce air pollution and some of the grasses as *A. stolonifera* and *E. rubra*, are more effective than *P. lanceolata* and *S. album* at capturing PM₁₀. Even more effective ways increasing the air pollution deposition are green walls. In densely polluted street canyons these could reduce the street level concentrations of NO₂ for up to 40 % and PM up to 60 % (Pugh et al., 2012).

On the other hand, large trees on both sides of streets also contribute to reduced mixing, dispersion, and wind velocity and thereby increase air pollution levels at the street-level (e.g. Gromke & Ruck, 2009; Vos et al., 2012; Keuken and Valk, 2010). Bucciolieri et al. (2009) have shown the highest concentrations at the base of the windward wall. However, the situation could be improved by knowledge-based planning and modelling (combination of tree species, canopy volume, and geometry, wind speed, and direction) of green spaces (Amorim et al., 2013) as well as provision of fresh air along air flow corridors (Kazmierczak and Carter, 2010).

In urban areas BVOCs emitted by trees can cause increases in ozone pollution, acting contrary to the pollution-scrubbing effect. Not all species emit BVOCs at the same rate, therefore selection of low BVOC emitting species where possible can decrease the risk of high-ozone episodes (Calfapietra et al., 2013). Considering both pollutants removal and BVOCs emission, Donovan et al. (2005) have demonstrated that pine, larch, and silver birch have the greatest potential to improve urban air quality, while oaks, willows, and poplars can worsen downwind air quality if planted in large numbers.

In general GUI could influence local climate, carbon cycles, energy use and climate change (Nowak et al., 2013b). Climate change itself can also affect urban air quality negatively, e.g. by affecting dispersion condition due to more stagnant air masses and a projected decrease in ventilation in Europe, eastern North America and East Asia (Jacob & Winner, 2009). On the other hand, some climate neutral fuels such as local biomass burning might decline urban air quality due to higher emissions of PM compared to gas or light-oil (Haluza et al., 2012). There will also be CC effects in ozone levels due to a change in temperature, humidity, radiation and of transportation of ozone precursors, having different effect throughout Europe (Demuzere et al., 2010a,b; Orru et al., 2013). Moreover CC would influence BVOCs emissions that affect ozone levels due to precursor change and PM levels due to primary aerosol emission. Thus for the United States, the biogenic emissions model expects an ozone increase by 5–10 % in the Northeast area and a PM_{2.5} decrease by 5 % in the Southeast region in 2050 compared to 2000 (Lam et al., 2011). In that sense GUI does also have co-benefits for urban air quality while adapting to negative impacts on climate change.

2.2 Psychological and social benefits

Green spaces in cities do not only have a positive effect in terms of ameliorating urban (micro) climate and preventing heat stress phenomena. Proximity of green infrastructure has a positive effect on human health and well-being in a variety of domains (James et al., 2009; Perring et al., 2013). Urban ecosystems could potentially provide a diversity of recreational and psychological benefits, as well as opportunities for community bonding and education for better coping with adverse effects of climate change.

2.2.1 Health and restorative benefits

When it comes to the physical health benefits of green infrastructure, a study by Mansor et al. (2012) suggests that green urban infrastructure increases residents' participation in physical, leisure and social activities, triggering relaxation, comfort and satisfaction. Good access to urban green spaces is associated with higher use, higher physical activity levels, and a lower likelihood of being overweight or obese (Coombes, 2010). Maas et al. (2010) demonstrated how the annual prevalence rate of 15 of the 24 disease clusters was lower in living environments with more green space in a 1 km radius. The relation was strongest for anxiety disorder and depression and stronger for children and people with a lower socio-economic status. Allotment gardening is shown to have a particularly positive effect on the health and well-being of older gardeners, who enjoy active gardening whereas younger generations tend to enjoy passive relaxing on allotments (van den Berg et al., 2010). Urban green spaces are recognized as a means which encourages active and healthier forms of travel such as walking and cycling (Coombes, 2010), and as a result can help to reduce carbon emission. A study by Niemelä et al. (2010) suggest that a loss of urban green areas can result in an undesirable outcome from the perspective of climate change mitigation, as urban dwellers have to commute to find recreational services.

In relation to mental health quality, neighbourhood green space enhances health by mitigating stressful life events, e.g. at the times of social and environmental perturbations (van den Berg et al., 2010). Similar conclusions are drawn by Abkar et al. (2010) about people that visited urban green areas: most of the interviewed people showed a positive mood change, feeling more relaxed and less stressed. Korpela et al. (2010) showed that there is a link between the need for restoration (worries and stress), the use of environmental self-regulation strategies (favourite places), and restorative outcomes. The more comfortable the perceived thermal comfort conditions, the more time people spent in the different places.

Evidence suggests that an increase in average global temperature is likely to be accompanied by an increase in aggressive feelings (Andersson, 2001; Hsiang et al., 2013). Use of urban green spaces has been examined to alleviate thermal discomfort during periods of heat stress. A study by Laforteza et al. (2009) among the users of green spaces in Italy and the United Kingdom showed that longer and frequent visits to green spaces may alleviate the perception of thermal discomfort during periods of heat stress. Results suggest that green spaces offering shaded locations and accessible water could benefit people and, to some extent, alleviate symptoms of thermal discomfort under heat stress conditions. The number of people seeking shade in green areas increases rapidly with thermal conditions (Thorsson et al., 2004, 2007). Analogously, Tzu-Ping Lin et al. (2012) and Lenzholzer (2012), emphasize trees shade importance to improve thermal comfort and parks attendance (especially during summer).

2.2.2 Social and individual coping capacities

The resilience refers to the inner strengths and coping resources for necessary adaptation to situational demands such as climate change (Swim et al., 2010). In this respect, GUI may promote individual as well as community level coping capacities.

On the individual level, apathy to climate change and the related inaction has been associated with the realisation of the magnitude of climate change threats and perceived inability to affect their outcomes (Lertzman, 2012). By contrast, the perceived ability or inability to take corrective action is one of the key determinants of going along CC adaptation or mitigation activities (Kates, 2007).

Perceived control can work in favour of action. There are opportunities for enhanced personal meaning and satisfaction from engaging in climate change mitigation or adaptation activities (Johnson et al. 2007).

People acting as stewards of their environment through community gardening, park management or watershed restoration (Krasny and Tidball, 2009), may contribute to the feelings of self-efficacy in making the environmental conditions more favourable around them. There may be a potential for enhanced personal meaning and satisfaction regarding effective efforts at climate change adaptation or mitigation (Krasny and Tidball, 2009). Evidence from research on some youth climate education programmes has shown that participants gain in self-efficacy, social competence, and a sense of civic responsibility (Johnson et al. 2007).

In the case of communities, the social strengths of a community such as pooled resources, knowledge, social support and social capital (Bonnano, 2004, Schoon, 2006) enables adaptive responses to climate change. More green space in people's living environment coincides with feelings of togetherness and perceived social support (van Dillen et al., 2009) necessary for such adaptation. Zaid et al. (2009) conclude that green areas promote community bonding and socializing, by participation in activities such as gardening. Analysis by Krasny and Tidball (2009) suggests that in high density urban areas green space in people's living environment is essential for social interaction and community satisfaction, and as such they may contribute to the resilience of communities in the face of perturbations such as environmental extremes, floods, conflicts or food insecurity.

Green infrastructure may offer space for comforting social interactions during climate-related extreme events. As Laforze et al. (2009) have shown, during thermal stress people living alone reported higher benefits from green urban infrastructure than people living in families with or without children. Kazmierczak's (2010) analysis shows that opportunities to socialise in the local green areas may be particularly important for more vulnerable societal groups, e.g. elderly, those in poor health, or those with young children that tend to have limited access to social networks, which can be crucial for mutual help at the times of ecological or social perturbations.

Various types of GUI allow for different degrees of social interaction and social ties to be formed. In general, visitors engaging in social activities during longer visits (afforded by parks of good quality), tend to form more extensive social ties (Kazmierczak 2010). Bendt et al. (2012) draw out a trade-off between broad-based participation in more open and interactive types of managing a local green area that reach out to a large numbers of people and more closed and well-institutionalised gardening types where long-term social ties are formed and maintained.

A stronger place attachment should promote climate-positive behaviour, as individuals are more likely to act carefully in a place that they value (Gifford, 2008). Some studies show that green urban infrastructure, public urban space, parks and allotment gardens also promote place-making in neighbourhoods (Bendt et al., 2012). A case study in Stockholm (Barthel et al., 2010) shows how urban allotment gardens foster sense-of-place, and create and help to maintain social-ecological identities. It needs further analysis to clarify the relationships between the feeling of place in urban environments and supporting climate friendly solutions e.g. creating green infrastructure.

As for the more practical strategies for adapting to climate-related adverse effects, Barthel and colleagues (2013) argue that urban gardening can build local ecological and social response capacity against major collapses in urban food supplies that may occur due to climate change,

environmental shocks and resource scarcities but also due to volatile economic systems. Urban gardens provide a unique and distinctively effective means of retaining and transmitting traditional knowledge of how to grow food. As an example, in Stockholm allotment gardens such collective memories are maintained and reinforced through exchange of seeds and recipes, self-enforced rules and everyday conversations (Barthel et al., 2010).

2.2.3 Education

Psychological studies show that ignorance and uncertainty, besides the effects of denial and habit, can be considered primary psychological obstacles to taking adaptive or mitigation actions towards climate change (Swim et al., 2010). Also, fear and anxiety can often hinder clear thinking and necessary adaptive responding in situations of environmental hazards (Reser, 2007).

Evidence from studies on the effect of urban environmental training programmes (Hashimoto-Martell et al., 2011) shows that increased awareness of the surrounding environment does not necessarily promote pro-environmental behaviours. It is suggested that more practically-oriented and hands-on learning curricula would enable to better understand the depth and delicate balance of cause and effect relationships between their own actions and ecosystem (Dearborn and Kark, 2010).

Green urban infrastructure offers various possibilities for more systematic and contextual understanding of the processes behind the climate change and the ways in which to mitigate or adapt to the related adverse effects. A study by Bendt et al. (2012) on collectively managed public-access community gardens (PAC-gardens) in Berlin showed that personal experiences in gardening activities and knowledge exchanged with other participants taught participants about climatic conditions and other ecological circumstances necessary for maintaining urban green ecosystems.

Different components of GUI offer various kinds of learning experiences. For example, allotment gardens foster experiential learning about local ecosystems, providing social-ecological memories of gardening skills and local ecosystems (Barthel et al., 2010). Decades of experience of gardening and park management may retain in-depth local knowledge about local climate variability and other ecological conditions for gardening. By contrast, PAC type of gardens are more open to broader public and interactive types of managing a local green area enable create broader and more heterogeneous learning about environmental (e.g. climatic factors) and social pressures that condition creating and maintaining green urban infrastructure. The examples from Berlin by Bendt et al. (2012) showed that PAC- garden's self-generated social and physical structures create greater autonomy, information-sharing between gardeners, give experiences of negotiations and decision making with city authorities and competing interest groups (e.g. estate developers). In a similar vein, a study by Krasny and Tidball (2009) about community gardens in North America, where youth learn alongside adult community gardeners, showed that such environmental education programmes offer participants active involvement in all aspects of solving environmental problems. Learning streams included gardening and local ecological conditions, urban politics and the role of civic action.

3 Spatial scales, co-benefits and trade-offs

3.1 Dealing with complexity by identification of relevant spatial scales

For planning and managing GUI as source of benefits for climate change mitigation and adaptation, it needs to be approached holistically, taking into account diverse spatial-temporal dynamics in benefit production including interactions between services. Linkages between benefits and the GUI components producing the underlying services vary spatially; services from GUI can contribute to benefits at the same site where the service is produced (restoration benefits from direct nature contact), in surroundings of the site (benefits from pollination), in areas in a specific direction (reduced problems with drought because of soils storing water in the upstream areas) or globally (CO₂ reduction) (Fisher et al., 2009). Services and benefits can be generated differently depending on the time perspective considered, e.g. trees provide shade for cooling in sunny time only and effects of changes in land use or management of GUI can be realized in more distant areas when more time has passed. Education of children is an example of an issue worth considering with a perspective of decades, as it can lead to long-lasting new benefits as the children's generation takes over the decision-making on the environment.

To support dealing with these complexities in a holistic approach, we summarized the evidence discussed above first in terms of their spatial scales. Figure 4.4.2 summarizes the relevance of the benefits from GUI on different spatial scales based on the evidence. Relevance means that GUI components (green and blue areas and elements) at the particular scale produce services needed for this benefit and addressing production of the benefit requires attention to this particular scale. Acknowledging that appropriate scales for an analysis depend on the particular issue at hand (Sayre 2009; Scholes et al., 2013), we choose a scale set (city-region, neighbourhood-district, site-block) that would help in considering scalar aspects of each benefit but still be simple enough to allow a general overview. Benefit-specific and service-specific analyses could use more tailored scale sets, for example analyses of mitigation benefits could benefit from use of scales wider than urban region, to consider mitigation as a global issue. As demanded adaptation benefits vary greatly by local conditions and related vulnerabilities (e.g. Biesbroek et al., 2010), it may be useful for urban regions to adjust adaptation-oriented scalar frameworks for their specific local purposes.

The evidence discussed above is not all-encompassing but as it covers at least an essential part of the recent literature, some conclusion can be made. Based on the evidence, three of the benefits/benefit sets are relevant in all three scales: improved water quality, reduced problems with flooding, peak flows and drought, and health and restorative benefits, social and individual coping capacities and education. Water related benefits arise from services linked to regionally functioning water system, whereby ignoring the regional scale could lead to management degrading the system as a whole. Ignoring the smaller scales, in turn, could lead to land use and management solutions altering water connections within the sub-catchments and thereby, for example, preventing storm water from flowing to a green area in which it could be purified.

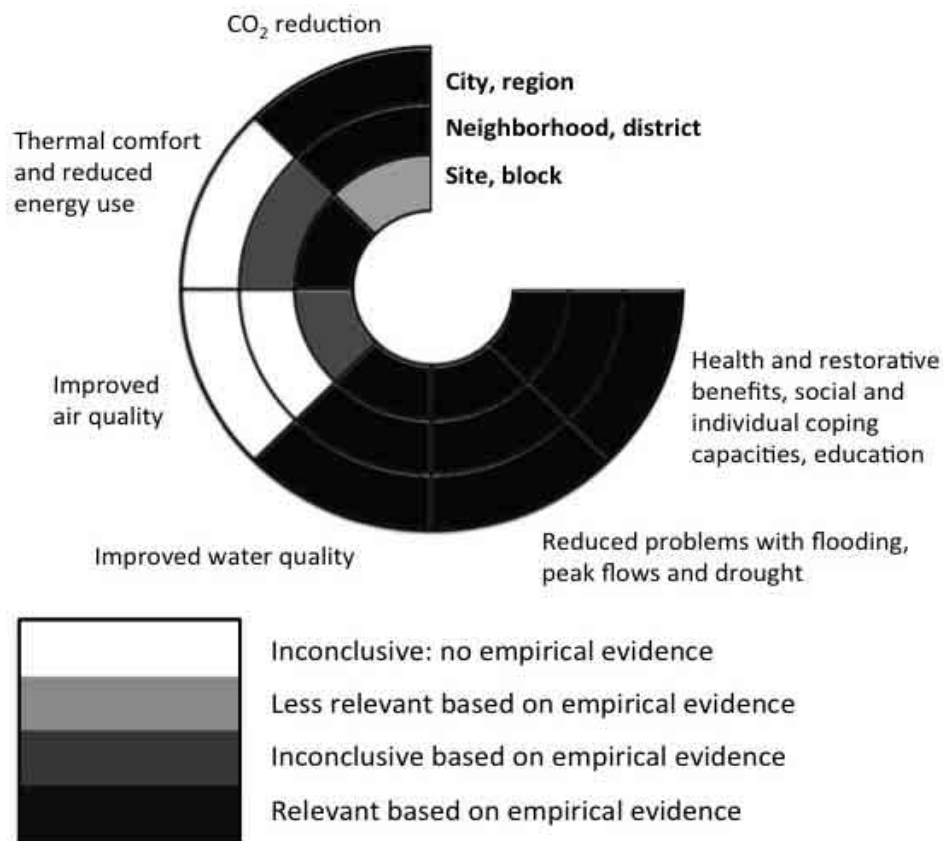


Figure 4.4.2 Relevance of the benefits from GUI for climate change adaptation and mitigation on three spatial scales, based on the evidence discussed above. The underlying data and definitions of the categories are presented in an Appendix to Section IV-4.

Evidence on health and restorative benefits, social and individual coping capacities and education differs from the evidence on the other benefits addressed in that linking it to spatial units is challenged by the complexity of human experiences and behaviour, e.g. variation of cultures, lifestyles, mobility habits and place relations of urban inhabitants. The spatial scale set is not sensitive for social scales such as the individual, a family or a group, however, it enables a general level consideration of the psychological and social benefits together with the other benefits as part of a holistic approach. The psychological and social benefits are relevant in all three scales. Site scale e.g. because of site characteristics define how the environment can be experienced, and the wider scales e.g. because accessibility of opportunities to specific experiences and equity of the accessibility is dependent on land use solutions on these scales.

Thermal comfort is an example of a benefit with which it is possible to define one scale as especially important, the scale of site/block. The cooling effect of a green area beyond its boundary is supported by few studies; most of them are simulations, especially those referring to whole city scale. Effects of GUI on thermal comfort and reduced energy use are linked to characteristics of vegetation and vegetated surfaces e.g. in urban street canyons and parks and on buildings, necessitating the small-scale analysis. These benefits may be relevant on neighbourhood/district scale as well, however, based on the evidence, it is useful to address their generation primarily with attention to GUI characteristics on site/block scale.

Improved air quality was the most uncertain of the benefits studied. As air purification service can vary significantly by detailed GUI characteristics such as tree type and location of vegetation in relation to buildings, and effects of this service have been demonstrated only on site/block scale,

this scale deserves attention. However, the evidence is not particularly strong in confirming the claim that GUI is beneficial for improving air quality. Based on the evidence the role of GUI in improving air quality may be so dependent on case-specific local characteristics that general conclusions are difficult to justify.

In this analysis CO₂ reduction was the only benefit for which it was possible to define a less important scale. Site/block scale is less relevant because the benefit makes sense when the volume of CO₂ sequestration and storage is large, and for this, large green areas are important but a single site insignificant. If large areas are lost by lack of attention to wider scales, the lost volumes are impossible or at least difficult to compensate by site/block scale solutions.

3.2 Co-benefits and trade-offs

Our review suggested that there are relevant co-benefits and trade-offs that require attention in addressing the production of services and benefits. Figure 4.4.3 illustrates co-benefits and trade-offs between different services and benefits, based on the examples of the types of green infrastructure that favour the benefit (trees, green roofs, rain gardens, etc.).

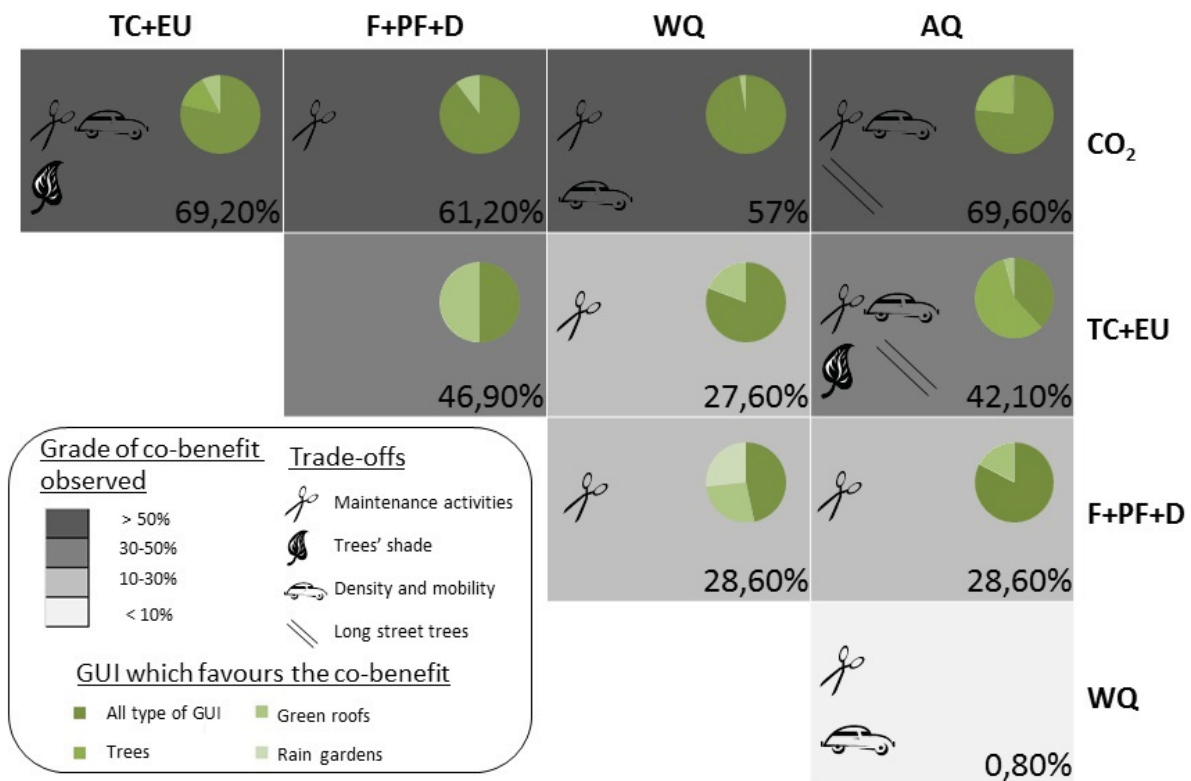


Figure 4.4.3 Co-benefits and trade-offs caused by GUI. The following abbreviations are used: TC+EU: Thermal comfort and energy use reduction, F+PF+D: Reduced problems with flooding, peak flows and droughts, WQ: Improved water quality, AQ: Improved air quality, and CO₂: CO₂ reduction.

The grade of co-benefit observed is the result of the analysis of each paper and the papers about the other benefits (cross-matrix method). For example, if a paper proves that trees are beneficial for CO₂ reduction and 50% of the papers about thermal comfort and energy use come to the same conclusion, then we have a 50% co-benefit between the benefit of CO₂ reduction and thermal comfort and reduced energy use. From Figure 4.4.3, it can be concluded that CO₂ reduction services favour co-benefits with other services, basically because almost all the types of GUI are beneficial for CO₂ reduction. The service with fewer co-benefits is the improved water quality, mainly

because the types of GUI established specifically for this purpose can be very particular and are not necessarily used for producing other services. The types of GUI elements that most favour the co-benefits are not clearly reflected in the analysis, but it can be concluded that CO₂ reduction and air quality are more related to trees. Water services, in turn, are more oriented to green roofs and rain gardens. Thermal comfort and energy use reduction services find co-benefits in both these types of GUI.

In addition to the co-benefits, also trade-offs occur. These are generally not addressed except for those studies that attempt to approach a specific problem via e.g. a life cycle assessment approach (Spatari et al., 2011). Based on our review, the following trade-offs can be identified:

- Maintenance activities: various maintenance activities emit carbon back to the atmosphere via fossil-fuel combustion (e.g., construction, transport). Fertilization can also be a problem, for example when an intensive green roof requires frequent fertilization which reduces the quality of stormwater runoff (Berndtsson, 2010).
- Trees' shade: very important in cold climates, as shade can reduce solar radiation penetration, increasing winter heating demand and reducing thermal comfort in streets, parks... (Tzu-Ping Lin et al., 2010; Forestry Commission, 2013; Maher, 2013).
- Large street trees: large trees on both sides of streets could as well contribute to reduced mixing, dispersion, and wind velocity and thereby increase air pollution levels at the street-level (e.g. Gromke & Ruck, 2009; Vos et al., 2012; Keuken and Valk, 2010).
- Density and mobility: as long as one city has extended green areas, the population density generally reduces, increasing mobility and fuel consumption.

4 Conclusion

Section IV-4 has provided clear evidence that an increasing body of knowledge related to the estimation of the benefits provided by GUI to CC mitigation and adaptation is available. It can be concluded that the topic is gaining momentum and that many empirical studies are producing outcomes that can be used to plan and design GUI to lower the vulnerability of urban areas to CC effects. However, the review showed also that it remains difficult to provide unambiguous conclusions on the actual contribution of GUI, due to the fact that many studies that provide evidence on the role of GUI are undertaken under specific conditions and assumptions. Future research should thus elaborate, and provide more general conclusions, on the potential of GUI, particularly with respect to:

- The role of GUI in contributing to CC mitigation and offsetting urban carbon emissions. Particularly, the potential CO₂ storage and sequestration of unconventional (building-integrated) green space, such as green roofs and green façades, for which robust data are still lacking;
- The impact of greening interventions on thermal comfort on the wider urban area;
- The cooling effect of green roofs in different types of buildings, and for the different seasons;
- The absorption of air pollutants by different types and composition of GUI; and,
- The cumulative effect of GUI on runoff, groundwater recharge and evapotranspiration, considering local physiographic, climatic and biotic aspects.

Concerning the analysis of trade-offs and co-benefits, it can be concluded that many GUI elements can provide multiple benefits for urban environments. This should be taken into account in planning and design, e.g. in assessing the usability of specific greening techniques in different types of areas. Consideration of the multi-functionality is particularly important as the case of looking at one

benefit only could in turn be detrimental from another point of view (trade-offs). Another conclusion is that defining the scales of benefits carries several practical advantages. First, on the individual level, indicating the concrete benefits of GUI for climate change adaptation and mitigation will reduce the uncertainty of climate change and the global nature of its potential effects that are recognised as the universal barriers to effective behavioural responses. Difficulties to act now for perceived distant future or potentially far-away negative impacts of climate change have been attributed to a cognitive tendency of dampening of reactions and judgements with the increase in spatial and temporal distance of risk (or decrease in personal benefit from counteractions) (Swim et al. 2010; Pidgeon, 2011). Evidence on the spatially defined benefits of GUI measures for CC adaptation can motivate citizens in the urban region to undertake often costly or difficult changes to behaviour. Second, on the level of political and administrative decision-making, better understanding of the spatial scales of GUI benefits lies in improved ability to set policy objectives and responsibilities at appropriate administrative levels. Understanding of the benefits from GUI allows employing specific competences of regional and local level authorities in urban greening initiatives.

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Appendix

A benefit was defined as relevant on a scale when the evidence included from several studies arguments indicate that this scale requires attention in addressing provision the benefit in planning of GUI because 1) the benefit is dependent on GUI components or characteristics on this scale and 2) this scale enables consideration of the relevant GUI components and characteristics better than some other scales. A benefit was defined as inconclusive when the evidence was conflicting or unclear in this regard (inconclusive based on empirical evidence) or evidence was lacking (inconclusive: no empirical evidence). A benefit was defined as less relevant when there were arguments from several studies showing that for addressing production of the benefit there are other scales that are clearly more useful than this one.

Table 4.4.1 Extended overview of the relevance of the benefits in different spatial scales based on the evidence studied.

Services and benefits	GUI Source	Site, block	Neighbourhood, district	City, region
CO ₂ sequestration and storage > CO ₂ reduction	Vegetation (sequestration), biomass, soils (storage)	For CO ₂ sequestration and storage the total regional capacity matters, single site insignificant; this scale less relevant.	Green areas and elements contribute to CO ₂ sequestration and storage (Jo 2002; Zhao et al. 2010; Davies et al. 2011; Hutyra et al. 2011; Ismail et al. 2012; Nordbo et al. 2012; Raciti et al. 2012; Strohbach et al. 2012; Nowak et al. 2013); this scale relevant for planning areas with these characteristics.	Green areas and elements contribute to CO ₂ sequestration and storage (see neighbourhood and district scale); this scale relevant for planning areas in the region from this point of view, especially identifying areas with greatest volume for carbon storage.
Cooling > Thermal comfort, reduced energy use	Vegetated surfaces, shading vegetation	GUI components contribute to cooling locally (Potcher et al. 2006; Yu and Hien 2006; Chang et al. 2007; Alexandri and Jones 2008; Shashua-Bar et al. 2009; Bowler et al. 2010; Castleton et al. 2010; Cheng et al. 2010; Cameron et al. 2012; Cook-Patton and Bauerle 2012); this scale relevant for designing urban space from this point of view.	Some evidence on green areas contributing to cooling beyond their boundaries (Yu and Hien 2006); this scale relevant for planning location of green areas in the urban form from this point of view.	No evidence on GUI contributing to cooling at this scale, though it has been suggested that GUI may matter for reducing urban heat island (Pataki et al. 2011; Santamouris et al. 2012).
Water cycle, e.g. water retention > Reduced problems with flooding, peak flows and drought	Vegetated and other permeable surfaces, soils with good infiltration capacity, designed features such as bioswales	Site scale features such as green roofs, infiltration at parking lots, infiltration trenches, bioswales and rain gardens contribute to these benefits (Carter and Rasmussen 2006; Mentens et al. 2006; Hunt et al. 2008; Li et al. 2009; US EPA 2010; Odefey et al. 2012; US EPA 2013).	Retention capacity requires a matrix of corridors and patches in areas with soils having high infiltration capacity (Gill et al. 2007; Eijs 2013); site scale too detailed to address these, while regional scale may miss spatial differences in the region.	GUI components affect water flows towards receiving water bodies and an urban area is affected by changes in vegetation cover in the upper parts of the catchment area (Gill et al. 2007; NRCNA 2008; Eijs 2013).

Water cycle, e.g. filtration > Improved water quality	Vegetated and other permeable surfaces, designed features such as bioretention systems and bioswales	Site scale features such as bioretention systems, bioswales, artificial wetlands and green roofs contribute to improved water quality (Hunt et al. 2008; Davis et al. 2009; Gregoire and Clausen 2011; Xiao and McPherson 2011).	For site scale features to contribute to quality of water flowing downwards in the catchment area, the sites need to be linked to the water system in the catchment, for example through connected green corridors and patches (Gill et al. 2007) that need to be designed at a level wider than site (see water retention above).	Besides affecting water flows towards receiving water bodies, GUI components affect also the quality of the water flowing (Backstrom 2003; Farrell and Scheckenberger 2003; Wadzuk et al. 2010; Odeley et al. 2012)
Purification of air > Improved air quality	Vegetation	Some evidence on vegetation contributing to air quality locally (Beckett et al. 2000; Donovan et al. 2005; Freer-Smith et al. 2005; Tiwary et al. 2009; Mitchell et al. 2010); this scale relevant for designing urban space from this point of view.	No evidence on green areas contributing to air quality in the surrounding areas.	No evidence on GUI contributing to air quality in this scale. This scale could be relevant in planning location of pollutant sources (e.g. motorways) in relation to GUI, to use GUI in reducing the dispersal of pollutants.
Spiritual and intellectual interactions > Health and restorative benefits, social and individual coping capacities, education	Elements and areas enabling experiences with nature	Contact with nature contributes to health and restorative benefits, learning and conditions for coping capacities (Johnson et al. 2007; Krasny and Tidball 2009; van Dillen et al. 2009; Zaid et al. 2009; Abkar et al. 2010; Barthel et al. 2010; 2013; Coombes 2010; Korpela et al. 2010; Van den Berg et al. 2010; Mansor et al. 2012; Bendt et al. 2012; Kazmierak 2013); this scale relevant for designing GUI as part of the urban space from the point of view of experiences and activities.	Evidence on benefits (see site and block scale) and the importance of easy access to green areas (Coombes 2010; Maas et al. 2010); this scale relevant for planning access to opportunities for experiences and activities from the points of view of different population groups, e.g. vulnerable groups, and for building social coping capacities.	Evidence on benefits (see site and block scale); this scale relevant for planning diversity of opportunities for experiences and activities in the region and equity of access to these opportunities in different parts of the region from the points of view of different groups, considering also lifestyles connected to region rather than a neighbourhood (Vasanen 2013).



Artist: Kid Acne, Photographer: Dave Surridge

A policy and governance context for integrated urban sustainability strategies

Section V

A policy and governance context for integrated urban sustainability strategies

Stephen Dobson¹, Sonia De Gregorio Hurtado², Dulce Coelho³,
Annemie Wyckmans⁴, Karel Schmeidler⁵

¹Sheffield Business School, Sheffield Hallam University, Sheffield, S1 1WB, U.K.; s.dobson@shu.ac.uk;

²Universidad Politecnica de Madrid, Madrid 28040 Spain; sonia.degregorio@upm.es

³Polytechnic Institute of Coimbra-ISEC, Portugal; dcoelho@isec.pt

⁴Institutt for byggekunst, historie og teknolog, Norges Teknisk-Naturvitenskapelige Universitet, Norway,
annemie.wyckmans@ntnu.no

⁵REDECO Ltd. Brno, Czech Republic, Kal@seznam.cz

Highlights

- A comparison of regeneration strategies in the UK, Norway, Spain and Portugal illustrate a context of urban uplift and investment in cities.
- Sustainable development requires an integrated approach built through partnerships and public participation. Lessons are presented here from collaborative planning in Brno, Czech Republic.
- The complexity and multi-stakeholder challenges are underlined particularly within a growing need to build public-private partnerships thus seeing shifts toward an entrepreneurial urbanism.
- A Soft Systems Methodology, demonstrated in Portugal, is presented as a practical means to support complex and multi-stakeholder decision-making environments.

1 Introduction

The urban built environment creates an intricate web of linked neighbourhoods, combining high inertia in spatial, policy, and governance structures with rapidly changing functionality and uncertain futures in climate, demographic, socio-economic and other urban challenges. Improving the sustainability of urban areas needs to take place through holistic and integrated projects, linking structure to agency in a multidimensional manner. Urban regeneration and its instruments can play a relevant role to achieve this goal.

This section presents examples of issues and challenges relating to sustainable development decision-making contexts. Firstly, it provides a brief comparative review of urban regeneration strategies in the UK, Norway, Spain and Portugal. Innovation and flexibility through increased public participation emerge as key areas and further explored in a Czech Republic context. A decision support approach through Soft Systems Methodology is then presented from Portugal to help provide guidance on mediating complex multi-stakeholder planning through an energy planning context.

Urban regeneration policy from four different European contexts with different urban policy traditions: Norway, Portugal, Spain and the United Kingdom (UK) are considered. It compares the urban regeneration policies developed by national Governments to introduce and implement “methodologies” for action in urban areas based on flexible instruments aimed at improving urban neighbourhoods, creating capacity and added value for future resilience. Governance issues are central in urban regeneration methodologies. International guidelines in the framework of sustainable development as well as the scientific literature and experience on this topic point out conditions that favour the development of sustainable urban regeneration policies are:

- The inclusion in the decision-making processes of all the actors with a stake in them;
- The inter-departmental collaboration (in order to overcome singular sectoral visions); and,
- The collaboration between the different tiers of government.

Urban regeneration instruments are playing a relevant role in order to help cities tackle deprivation in neighbourhoods in crisis. The first experiences, mainly in the United States (US), the UK and France have been relevant in shaping the regeneration responses by other European countries and the European Union (EU). In turn the “urban policy” of the EU has influenced remarkably the path undertaken by the member States that had been more reactive to develop a national urban policy in which urban regeneration was explicitly included and funded. The urban policy of the EU has evolved throughout the 1990s on the basis of different experiences (among which it is worth mentioning the two rounds of the URBAN Community Initiative), giving place to what was called at the beginning of the 2000’s “Urban Acquis”, a set of common principles oriented to undertake a more coherent approach to urban policy (MIKR, 2004). The vision of urban development provided by the Urban Acquis specifically addressed governance issues: “national, regional and local sectoral policies should be better integrated” (Ibid 2004, p2), “public, private and community partners in cities should engage in constructive working relationships” and “citizen’s participation should be based on dialogue with experts to stimulate citizens’ ownership of the urban living environment” (Ibid, 2004, p4). Previous and subsequent documents of the EU have maintained this approach. For example the Leipzig Charter considers governance transformation as a crucial tool for the implementation of the integrated approach in sustainable urban development (Leipzig Charter on Sustainable European Cities, 2007).

As mentioned, European national governments have developed different strategies to address urban decline. Some of them have been pioneers, implementing urban programmes to tackle social and environmental problems from the sixties, while others have not developed explicit policies until the last decade. At the moment most of them are implementing urban policies to revitalize deprived areas and to spur transition towards more sustainable urban futures. In the most vulnerable areas collaborative instruments for urban regeneration are able to introduce innovation and flexibility in planning systems governance, so as to start processes of capacity building in cities that ultimately can result in the transformation of local governance models.

This work undertakes a comparison of regeneration instruments developed and implemented by the Norwegian, Portuguese, Spanish and UK national governments. It identifies the approaches to enhance collaborative and integrated urban regeneration models and underlines common problems .

2 Urban regeneration an analysis of four European cases

A summary of urban regeneration approaches that have been developed in Norway, Portugal, Spain and United Kingdom over the last decade is provided below. The focus is on the governance approaches in which they have been based in order to understand how they are enhancing collaborative methodologies to create adaptive capacity in cities. This provides an understanding into the similarities and differences in which they are tackling this common challenge governing the implementation of sustainability and regeneration.

2.1 Portugal: The Policy for the Cities (POLIS XXI)

The Portuguese Government has established, as a priority, to develop the capacity of cities to become active centres for innovation, competitiveness and participatory citizenship and to improve the quality of life. Between 2005 and 2007 a coordinated comprehensive set of integrated urban policy instruments was launched, aimed at promoting city regeneration, competitiveness and innovation through networking, as well as at improving quality of life in the urban environment. It was designed and adopted under the name Policy for the Cities POLIS XXI (2007-2013) (Direcção-Geral do Território, 2013).

The Policy for the Cities POLIS XXI lays its foundations on the Portuguese National Spatial Policy Programme (PNPOT) (DGOTDU, 2013a) adopted by the Parliament in July 2007 which is aimed at strengthening the national urban system, making cities more competitive and attractive to live and work in, avoiding urban sprawl, promoting urban regeneration, improving the quality of public space and built environment, functionality and energy efficiency, modernising infrastructure and service, ensuring social cohesion and employment. Based on a diagnosis of current territorial and urban constraints, challenges and potentials, PNPOT draws a comprehensive action plan for territorial and urban development, with a sustainable development perspective.

The POLIS XXI Program benefits from the accumulated experience at international level (here it is worth mentioning the URBAN Community Initiative) and national level with the POLIS Program. The POLIS Program is a program for urban renewal and environmental upgrading of the city (Council of Ministers Resolution N°. 26/2000) that has been running between 2000 and 2008. The main aim of the POLIS Programme was the improvement of the quality of life in cities, through interventions in urban and environmental areas, improving attractiveness and competitiveness in urban centres that have an important role in the national urban system. The POLIS Program involved large integrated interventions in 28 Portuguese cities, 18 were pre-chosen in launch of the program and were 10 chosen by tender. In addition other smaller interventions in 12 cities were as part of the the UNESCO World Heritage list (<http://www.polis.maotdr.gov.pt/>).

The operational aims from the Policy for the Cities POLIS XXI (2007-2013) are:

- To qualify and integrate the different urban areas in inclusive, coherent and sustainable cities, with active involvement of their inhabitants;
- To strengthen and to diversify the human, institutional, cultural and economic assets of each city, in order to broaden the range of opportunities offered to its citizens and to enhance the city's role at regional, national and international level;

- To qualify and increase the integration of the city in its surrounding region, in order to promote sustainable complementarities between urban and rural areas and to enhance the city-region's potential for development; and,
- To innovate in the field of urban development, by applying the integrated urban sustainability approach and promoting the efficiency of infrastructures, services and facilities, the control of urban sprawl, the use of ICT, local capacity-building and new forms of public-private partnerships (DGOTDU, 2013a).

Key stakeholders are involved in the implementation of the Policy for the Cities: the local authorities, companies, business associations, central administration services and other public entities, providers of public services, in particular in the areas of transport and environment, education establishments, vocational training and research, non-governmental organisation, residents and their associations.

The Policy for the Cities POLIS XXI (2007-2013) is implemented through a decentralized approach in line with the principles of initiative of local authorities, with selection by public tenders, with national and regional strategic planning and partnerships and contracting between central government and local authorities. It aims to support local initiative projects that will be selected through open competition procedures of national or regional level, depending on the program of public funding to be used. The role of the central administration is to define policy instruments. There are three policy instruments with different operational targets: Partnerships for Urban Regeneration (managed at regional level - 60 urban regeneration projects); City Networks for Competitiveness and Innovation (managed at regional level - 31 cities in networks) and Innovative Solutions for Urban Challenges (at national level - 75 projects).

The Cities Policy POLIS XXI Program contains funding mechanisms of various kinds such as tax exemptions and reduced fees; direct EU funding through the European Regional Development Fund (ERDF), the National Strategic Reference Framework (NSRF); public funding from the State budget and Municipal budgets (DGOTDU, 2013b).

2.2 Spain: The urban regeneration practice

During the period 2004-2011 the Spanish Government undertook activities consisting of the development of acts, propositional and guideline documents, creation of networks of exchange and benchmarking initiatives, and regeneration instruments (such as the Urban Initiative - *Iniciativa Urbana*- or the National Plan of Housing and Rehabilitation 2009-2011 -*Plan Nacional de Vivienda y Rehabilitación 2009-2011*) for the regeneration of deprived neighbourhoods. This set of actions was based on a reflection on the urban fabric and revealed a new interest in urban regeneration in stark contrast with the previously passive role played by the Central Administration. The focus and intensity, of this programme of activities had no precedent and made a significant contribution to the practice of urban regeneration. Indeed, a review reveals that the action undertaken by the Central Government could be seen as initiating real transformation in Spanish urban regeneration practice. It put urban regeneration in the centre of sustainable urban development in order to stop urban sprawl and make cities more resilient. The development of regeneration projects was based on flexible, strategic, multi-level, integrated and participative approaches where innovation and the capitalization of knowledge were promoted. The action described alone cannot introduce sustainable urban development criteria in regions, municipalities, the private sector and citizenship,

but it is a necessary step towards change in a country traditionally characterized by a fragmented, sectoral and non-participative approach in urban rehabilitation initiatives (De Gregorio, 2012).

The mentioned Urban Initiative and the National Plan of Housing and Rehabilitation, launched by the Central Government in 2007 and 2009 respectively, are based on the URBAN Community Initiative¹³, reproducing explicitly its collaborative and integrated approach, as well as other methodological aspects (such as the area-based approach, which concentrates economic and technical resources in deprived areas; the competitive bidding; or the six years timeline). As in URBAN, the most powerful transformative elements in both initiatives are the assumption of an integrated approach (that entails to act in the social, economic and environmental dimensions of urban decline) and the collaborative approach (that entails multi-level collaboration in the implementation of the regeneration initiatives, the cooperation of the relevant departments of the different levels of governments and public participation in order to open the regeneration project and its implementation to the local community). The combination of these elements aims to transform governance structures through the implementation of regeneration instruments in cities.

The 46 Iniciativa Urbana programmes (2007-2013) have not yet finished¹⁴, and so it is not possible to undertake an analysis based on their final results. Looking at the outputs of the round of projects to which the Iniciativa Urbana aims to give continuity (the 10 programmes of the URBAN II Community Initiative implemented in Spain during the period 2000-2007), it is possible to say that the development of the integrated and collaborative approach in the Spanish case have given place to the transformation of all the dimensions of governance regarding urban regeneration, acting as a “seed” of slow transformation. It has been particularly successful in the case of inter-departmental governance, which has benefited the inter-sectoral approach of the programmes, delivering more holistic strategies able to tackle the different dimensions of urban depravatio. In the case of the multi-level governance, the role of the regions was minimised, something that the Iniciativa Urbana has tried to avoid from the beginning, trying to involve regions in the implementation of the instrument as crucial stakeholders. This is a key aspect in a country where the competences on urban areas were devolved to cities and regions at the end of the 70’s and the beginning of the 80’s. Regarding public participation the results show that a different approach was applied by the 10 cities where the URBAN II programmes were implemented: a minority of cities implemented real participation, giving the local community the opportunity to have a say in the development of the proposal and the implementation of the measures; most of the cities developed participation processes that integrated the request of the local community in the proposal for action, but didn’t allow it to act as an active actor during the implementation of the regeneration programme. Finally a minority of cities implemented participation processes that consisted only in the provision of information to the local community. The strategies developed by the different programmes were implemented on the base of criteria that minimized, biased or reduced to information the participation processes, making visible the inertias that operate in the Spanish case regarding this particular matter (De Gregorio, 2012). The observation of the URBAN II projects identifies the necessity of supporting the transformation of the urban governance framework in the Spanish case, particularly regarding: the integration of the action developed by the different tiers of government,

¹³ The evolution of the Spanish practice of urban regeneration has being highly influenced by the urban policy of the European Union, and specially by its more specific instrument, the URBAN Community Initiative, that was implemented in the country through the development of 39 programmes from 1994 to 2007 (De Gregorio, 2012).

¹⁴ They will be completely finished in 2 years.

and the openness of the planning processes to all the actors with a stake in the areas where the regeneration programmes are implemented.

2.3 UK: Beyond the 'Urban Renaissance' and 'Neighbourhood Renewal'

Since the late 1990's urban regeneration in the UK has been significantly driven by two policy strands - these are commonly referred to as 'Urban Renaissance' and 'Neighbourhood Renewal'. The distinct but broadly complimentary approaches arose principally from the documents 'Towards an Urban Renaissance' (Rogers 1999) and 'Bringing Britain Together: A national strategy for neighbourhood renewal' (SEU 1998).

Urban Renaissance emphasised increased densification of urban development in declining towns and city centres as a means to encourage inward commercial investment and urban living. Coupled with a significant focus on design, it sought to achieve this with the creation of high quality and attractive urban environments. This was a distinctly European vision of the city with Barcelona explicitly being heralded as an ideal model. Positive change through good design and the regeneration of urban fabric underpinned this approach. The focus of Neighbourhood Renewal strategies differed somewhat in the sense that regeneration was more explicitly socially-driven specifically targeting deprived neighbourhoods. This was less about material renewal and more about tackling education, worklessness and health, and was in many ways a direct response to the 'top-down' approach to urban regeneration as typified by the Urban Development Corporations (UDCs) of the previous decade (Deakin and Edwards 1993). UDCs were essentially private planning bodies with the power to grant local planning permissions, compulsory purchase land for development, and to manage the land as necessary for their objectives. Whilst this was deemed necessary at the time to attract private investment UDCs were not strategic plan-making bodies and were also not bound by the strategic plans of local authorities. The partnership approach adopted both in Urban Renaissance and Neighbourhood Renewal policies a decade later sought to address this.

Whilst Urban Renaissance adopted a relatively targeted approach to city centre regeneration of architecture and public realm, Neighbourhood Renewal incorporated local partnerships (between local communities, local and national government agencies and private industry) as a mechanism to bid for resources to finance more community-focussed regeneration. By including social and environmental dimensions along with the economic, a more holistic approach to tackling urban deprivation was sought. However, reflecting upon renewal strategies and the associated gentrification of urban centres, Grainger (2010) asks:

"[...] whether urban areas have improved beyond flagship and amenity developments and new retail centres and water-fronts. In other words, is urban renewal, which is captured in its most explicit form in construction works and aesthetic investment in city centres, leading to actual lasting change or resolution of problems in those localities?" (Ibid 2010, p.9)

The key question is whether these strategies are sustainable. The age of austerity has now brought about a UK government focus on reducing structural deficit and what Tallon describes as a spatial urban policies and a "shift to local and city-wide enterprise and governance, with local authorities and local communities afforded a greater role." (Tallon 2013, p. 106). A question remains as to

whether there is sufficient capacity across multiple governance layers within local authorities to deliver these aspirations:

“Urban regeneration appears to have returned to the 1980s with the driving force being economic growth in response to the credit crunch and resulting global financial crisis and economic recession in the UK. At the same time, the philosophy of localism has been promoted and the regional level governance has been abolished. Limited additional resources have been provided by central government for these policies, with the emphasis being on encouraging market forces and attracting development to particular areas of cities.” (Tallon 2013, p.114)

2.4 Norway: Cities of the future programme

The Cities of the Future programme is the largest national programme addressing resilience, climate change mitigation and sustainable development in Norwegian cities (Framtidens Byer 2012). The programme (2008-2014) was initiated by the Ministry of Environment to improve quality of life in the 13 largest cities in Norway while reducing their greenhouse gas emissions. In addition to four Ministries, local and regional authorities, a wide range of industry, research and educational partners contribute to the programme in co-operation with their respective cities. The programme is based on four sectors in which each city is expected to develop and implement transition strategies across urban sectors, taking into account future environmental and socio-economic changes. The four main sectors are:

- Land use and infrastructure;
- Stationary energy use;
- Waste and consumption; and,
- Climate change adaptation.

Clear timelines, project organisation and financial models are proposed to fully integrate the programme into municipal regulations. Project results (positive and negative) are communicated to experts as well as laypeople in order to build awareness and knowledge. In this manner, the cities become a test bed for combining new technologies, policy and business models to regenerate environmental and socio-economic regeneration.

2.5 Comparison of sustainability and regeneration efforts

The four national approaches are firmly embedded in their socio-economic, historical and cultural context. However, many of the individual methods, tools and concepts described in them are present and, in principle, transferable to other cities, countries and even other continents. One of the primary challenges identified by this summary of regeneration policies is concerned perhaps not with the individual component parts deemed necessary for sustainable futures, but their integration. Political culture (at international, national and local levels), institutional architecture and governance provide an important context against which aspirations toward integration of urban functions and regeneration may or may not be achieved. From this perspective, even if the differences are remarkable, it is relevant to point out that all the countries have developed initiatives that aim to tackle urban deprivation from a holistic perspective, integrating social, economic, environmental and management dimensions. The integrated approach seems to be understood as a condition to be fulfilled to achieve sustainability at city level in the national contexts. The different

strategies implemented in the four national contexts reveal that the reality where urban regeneration is implemented determines what is understood as adapting urban capacity, conditioning the methods and contents of the initiatives developed to enhance it.

The similarities of the visions adopted - based particularly on the aspirations of: integrated approaches, the promotion of participation, and the flexibility of the methods as to be adaptive to different local conditions, the networking and exchange of knowledge, and the promotion of innovation, reveal that the four countries are addressing urban sustainability by assuming common principles of action in the field of urban regeneration. From this perspective, it is relevant to observe that countries without a tradition in urban regeneration policies, such as Portugal and Spain, are developing initiatives of urban regeneration with significant similarities to the British initiatives. The role developed by the urban dimension of the EU policies has been crucial to introduce urban regeneration instruments in the Portuguese and Spanish contexts (De Gregorio, 2012).

As can be observed a common element of the approaches and initiatives developed is the integration of mechanisms to transform local governance. In fact, all of them aim explicitly to involve stakeholders, citizens and decision-makers in partnerships or collaborative processes of participation in the context of different regeneration instruments. From this perspective all of them value the role of the communities in their respective regeneration programmes as a means to make a difference to the performance of cities and their adaptive capacity (through the integration of the non-expert knowledge in the urban strategies, the commitment of the community to the projects, the identification of the citizens with their neighbourhoods, the mobilization of local resources, etc.).

In the UK, mechanisms for governance included the adoption of urban management practice achieved through the creation of Town Centre Managers to coordinate and maintain urban renaissance projects and also Neighbourhood Management for renewal strategies. The latter was more predominantly community-focussed and participatory whereas the former, being dominated by investment in architecture and public realm, was overseen by UDCs. However, despite the concerns that earlier mechanisms for delivering regeneration through UDCs lacked continuity with the local strategic framework, Hall and Mawson (1999) identify that the shift to participatory approaches (based on partnerships bidding for funding resources) still lacked a coherent strategic framework. This ultimately has resulted in “[...] the focusing of regeneration activities of bidders to ‘perceived’ government priorities [and] the lack of a clear link between resource allocation and need.” (Ibid 1999, p2).

The evolution of the Spanish practice of urban regeneration has being highly influenced by the urban policy of the European Union, and especially by its more specific instrument, the URBAN Community Initiative (De Gregorio, 2012). The mentioned Urban Initiative and the National Plan of Housing and Rehabilitation, launched by the Central Government in 2007 and 2009, are based on the “URBAN method”, reproducing the its participative and integrated approach. As in URBAN the most powerful transformative elements in both instruments are the assumption of the integrated approach and the participative, inter-departmental and multi-level approach. Even if the analysis of the Spanish practice of urban regeneration shows an evolution towards inter-sectoral visions and the openness of the processes to non-public stakeholders, the inertia to change, the rootedness of traditional approaches, and the opposition from some stakeholders to transform the status quo, are aspects that are hindering the implementation of collaborative visions and as a consequence limiting the potential transformation of urban governance models that the regeneration programmes could

have starting. Similar results can be observed in the Portuguese case, where pre-existing practices and existing inertias are diminishing the potential results in the achievement of adaptive capacity in cities where the POLIS Programme has been implemented. In general the different approaches share as a significant problem the existing limitations to implement collaborative projects of urban regeneration in the context of collaborative multi-level frameworks.

2.6 Concluding remarks

The review undertaken reveals that the three countries integrated in the EU and the non-member country (Norway) are implementing regeneration instruments based in the same general common principles to give place to the construction of adaptive capacity in cities: the integrated approach, the transformation of local governance, and the construction of multi-level frameworks to implement integrated policies at national level.

The countries analysed, including countries (UK) with long experience on the implementation of collaborative approaches on urban regeneration, are experiencing problems to fulfil the collaborative vision. In the case of the Southern countries, existing inertias seems to be limiting the performance of the instruments proposed by the national governments.

The four cases reveal that a coherent framework is still needed to test the capacity of the instruments analysed of transforming local governance. In order to identify synergies and conflicts strategic change needs to be incorporated in long term urban regeneration policies to avoid the “construction of local capacity” remaining a theoretical or academic concept. This is particularly important in order to make the urban regeneration evolve towards more effective tools, able to face the limitations to transform local and multi-level governance identified during the last decade in the different national frameworks analysed. Experiences of the challenges in building public participation in planning are explored next in the case of Brno, Czech Republic.

3 Public participation in Brno, Czech Republic

The participation of the public within the preparation of urban development plans, projects, as well as implementation of new development and re-development projects has increased with the emphasis on spatial planning since the 1990s. Experiences from the Czech Republic are reported outlining the adoption of multidisciplinary approach that has embraced environmental psychology, urban sociology, municipal economy, statistics, architecture, urbanism, land use planning and legal studies. One of the strengths of the programme is the positive mix of professionals involved in the process of urban development. To accomplish the intended goals the research team co-operated with the research institute REDECO in Brno, and collaborated with specialised firms working in the field of the urban and regional planning and consultancy Aberton Shaw in Glasgow, FA VUT and GaREP institute in Brno.

3.1 The Participation of Local Population

The small and medium size Central European towns and cities in peripheral regions have suffered in post-war times due to lack of maintenance and proper development programmes, and under new conditions they require new attitudes for their revitalisation. Many procedures used in land use planning in these towns are arguably now outdated even though improvements are being made. This problem applies mainly to the Land Use Planning and Construction Act No. 50/1976 Coll. Its provisions are based on the directive management and central socialist planning. Previously, the

design process in architecture and town development in the Czech Republic became a technical administrative discipline, which was carried out without true participation of users and local citizens. The way this law regulated planning and zoning procedures was inappropriate and did not meet current needs of a democratic society, whereby municipalities seek to plan and create (shape) the local environment themselves. There was a lack of necessary procedures to support municipal development programs involving the participation of architects, urbanists, urban sociologists, town planners, economists and other specialists and regional authorities lacked sufficient documentation for regional development. In July 1997, 2002 and 2004 severe flooding has affected many of middle European regions and so there is now an even greater need to address the issue of revitalisation. In some instances major development projects will have to be adjusted in order to deal with immediate problems arising from disaster. Municipal authorities and their representatives keep on asking the Stern architects and planners, REDECO institute and Faculty of Architecture, Department of Urban Planning, Technical University Brno, Moravia for help in shaping the new development strategies.

The aim of the research project was, firstly, the modernisation and humanisation of cities and city environments and, secondly, the introduction of development strategies that can act as a mechanism for participatory and people-oriented planning procedures. The outcome of this project has been the establishment of a methodology for the creation of the development programmes together with its experimental verification. The methodology is universal so as to be applicable for different activities such as village restoration based on the renovation of the natural, architectural and social environment (renovation of the natural and man-made environment), and for humanisation of prefabricated housing estates, reconstruction of historical centres and degraded city parts. The marketing methods of the locality and organisational tools to fast track the planning system with reference to inward investment were also explored. This, on the other hand, should enable to emphasise the uniqueness of the environment and to enhance specific issues especially of small and medium size Central European cities.

3.2 Changing the role of participation

The participation of the public within the process of design or preparation of development plans, projects, as well as implementation of new development and re-development projects increased throughout the 1990s when architects, planners and citizen groups criticised the development of housing complexes demanding a return to traditional housing in the city. This democratic pressure influenced the political programme and as a result guaranteed public participation in the decision-making processes concerning important urban changes which is now part of the city's legal measures. However, public participation, requires a sensitive balance between the public and specialist opinion and such, stakeholder management and conflict resolution underpin the challenges associated with integrating sustainability measures. In the countries where 'user participation' has been accepted as an official approach the role of the planner has shifted somewhat to one of broker, negotiator and mediator.

The transition of the Czech Republic to a market economy and its democratisation has been far from stable, including incomplete economic privatisation, restitution processes, and fragmentation of its political sphere, power imbalance across local authorities, entrepreneurs and citizens (individuals and associations). The current experiences in citizen participation in the design process and process of town planning from the Czech Republic points toward the following:

1. Citizen participation is beneficial and advisable in the initial phase, during the elaboration of preparatory order documents of urban planning documentation. In the form of sociological survey of opinions on the development or transformation of the developed area may be gained, citizen's activities may brought under control in advance and thus cooperation may start as early during the formulation of conditions and demands for solution.
2. The most beneficial method of cooperation is a combination of legal procedures and voluntary negotiations (presentations of plans for inspection, citizens meetings, individual discussions), which brings commonly acceptable solutions.
3. Operative cooperation and participation of citizens require both time and personnel. Citizens meetings save time, but include a latent danger of haphazard decisions. A real dialogue with citizens with the evaluation of partial and general interests is more feasible in small discussions groups.
4. The more complex the task (project), the less influence on the part of citizens and the more clearly political goals have to be set down, procedures agreed, an unambiguous attitude of professional public has to be created and information spread through the media. It is suggested that local people should have more influence by creating housing, transport facilities and environment in the suburbs than in central city areas.

A significant question to arise from this process is around conflict resolution and the role of technical versus lay-person opinion. Full citizen cooperation requires a strong culture of involvement representing a citizen-focussed town administration, good local urban knowledge and a positive planning culture. The focal point of participation activities should shift from negativism, criticism and opposition to positive cooperation so that the lay-out of towns would result from a common will of their citizens as was the practice in classical times.

3.3 Local public involvement in decision-making

As a result, this project formulates new procedures for the design and pre-design strategies and city development (renewal) programs. This methodology should improve the process mentioned above and provide development programs for cities, towns and villages. Problems related to the urban revitalisation of medium and small cities were investigated. The methodology proposed was experimentally verified and results were offered to municipal authorities. The topic of this project proposal is very timely and important and, to the author's knowledge, solutions to this problem in such an extent have not been realised. The results of the project aim to unify the methodology with foreign partners in border regions.

The research was aimed to get verified results which may be applicable immediately in practice. The REDECO, Transport Research Centre and Urban Design Institute also have traditionally good contacts with municipal authorities and developers, which is very important for practical verification of developed procedures. Practical verification of developed procedures is possible by co-operation on ÚPD (project and planning) documentation with municipal authorities in Kromeríž, Pardubice, Týniště nad Orlicí, Prostějov, Prerov, Hodonín, Vsetín and cities/villages in border region South Moravia - Lower Austria. These authorities provided material (data) needed for research. As a result of this multidisciplinary research, social aspects enriched the process of design and development. The emphasis was given on data collection, their sociological interpretation and use in the environment shaping process. New methods and techniques applicable under current social and economic conditions were proposed and experimentally verified in this field. High

recognition has been achieved through successful design, consulting and scientific activities. The results of project were published in the form of a book (a final report). It is designated for architects, Urban and transport planners, and developers as well as for specialised municipal authorities. Collaboration is expected between faculties and design and planning studios in the future. The analysis and evaluation of current law is expected to bring suggestions for new amendments and other changes in legislation.

3.4 How to achieve quality decisions

There are no simple instructions for good decision-making. A suitable style of the decision making process differs from case to case. Experienced managers and their teams know when and how to take decisions on the basis of general principles and their application in the local context, which entails understanding the local environment, people and priorities. Decisions can be taken using various methods reflecting factors such as time, availability of resources and available information. To make informed decisions in the field of transport it is necessary to ensure both a quality project management as well a quality management in relation to the interest groups (Table 5.1).

Table 5.1 Typical interest groups.

Government/Authorities	Private entities	Local communities
European Union	Important employers	NGO's
Ministry for Regional Development	Local and nation-wide companies	Non-government ecological organizations
Ministry of Transport	Private financial institutions	Motor association
Other ministries	Local business associations	Trade unions
Regional authorities	Sellers, retailers	Media
Municipal authorities	Small-scale businessmen	Local organizations
Local Transport Authorities,	Transport companies	Local interest groups
Environmental and Town Planning Authorities		Bikers and pedestrians
Other local transport agencies		Users of public transport systems
Other local authorities and bodies		Car drivers
Politicians		Local Inhabitants
Other entities with decision making power		Visitors
Project managers		Disabled people
Other Professionals and Experts		Landowners
		Other stakeholders

3.5 Conflict of interest

Some public officers and representatives do not pay sufficient attention to the involvement of the interest groups either because they view spatial planning and infrastructure solutions (transport, energy, waste, etc.) as technical issues, or therefore should only be decided by experts. Or, alternatively it is because these local representatives consider themselves to be the best advocates of the interests of everyone, including the interest groups. Given the fact that various interest groups differ more and more in their interests and needs, but at the same time they demand a greater share in the decision making concerning projects having impacts on their lives, the complexity of this decision making process increases. The efficient involvement of all interest groups may help reduce their potential feeling of alienation. A meaningful manner of involving the interest groups may lead to many positive results, including: 1) Higher quality of development strategies, 2) Reduced costs

and restriction of time delays during the project implementation, 3) Smooth implementation of construction projects. So, how should it be achieved?

In the past, the most common task of the tools for the public and interest group involvement in the decision making process was to provide information, either through public meetings, leaflets, or notices etc. In most cases, this activity was subject to the applicable law. The common practice was also to proceed quite far in the process of selecting suitable solutions and only then determine the reactions of the public and strive after the involvement of the interest groups in the decision making processes. In recent years, the interests groups have started being involved in some projects already at the early stages of the decision making process and therefore they can contribute with their opinions and ideas to the specification of potential solutions. Those most demanded priorities by local citizens in Czech Republic include:

- Strict observance of the limits of pollution values ;
- Keeping attractive pedestrian zones ;
- Enough space for cars ;
- Emphasis on public transport services ;
- Smaller separation of town space by transport;
- Integration of all means of transport and support of cycling ; and,
- Transport safety.

The greatest neglect is related to the lack of involvement of the interest groups throughout the project duration, from the beginning to the implementation. This may lead to opposition on the part of the interest groups at the later stages of the project, which may have negative impacts on the budget and time schedule of the project. The next standard restriction is the provision of information to the interest groups without inviting them to react. In some cases, the involvement of the interest groups is minimal given the fulfilment of the local statutory requirements. The same minimal attention is paid to the applied methods and to how the reactions of the interest groups are handled by the project team. The main problem related to the standard practices is the absence of a systematic approach to the development of a strategy for the involvement of the interest groups.

The involvement of the interest groups enables their share in the decision making as well as the establishment of a partnership between the project team, local community, businessmen, local authorities and other entities that may assist the project implementation. The interest groups may contribute in a positive way to the decision making process at all its stages, from the method of defining the problems and objectives, to the evaluation of possible solutions.

However, the criticism of the process of involving interest groups often concerns the dissatisfaction of the groups with how their opinions are heard or included in the decision making process. To be able to avoid this, the strategy of the involvement of the interest groups should identify what topics and the interest groups through their opinions and inputs may affect aspects of the spatial planning and transport project. Once this point is decided, it should become the crucial component of the whole strategy and all planning activities.

3.6 Selection of a suitable technique

The selection of the most efficient technique of involving public and the interest groups is a key to the success of the whole process. A wrongly selected technique may cause not only poor results,

but under certain circumstances it can result in the creation of useless obstacles for the whole project if it seems that the decision making entities decide themselves who will be invited to be involved in the decision making and who will not. Therefore, various techniques may be used. There is no “correct” technique suiting all situations. It is only rarely possible to stick to the “pure” models. The use of more than a single technique may increase the probability of receiving a more representative response from the public. In any situation it is therefore necessary to make a suitable choice. The choice of the technique should be determined by who should take part in the decision-making process and what the purpose of this involvement should be. A role is also played by the availability of the relevant organization and its experience with the involvement of the interest groups as well as the availability of resources. Relevant planning and sociological publications and especially personal experience may be a partial guide when selecting the suitable techniques. The bullet points show questions that could help choose the suitable methods:

- Whose involvement are we striving for: public in general or specific interest groups?
- To what stage of decision making are we trying to involve the interest groups?
- Are we striving after a one-time form of involvement, or a continuous process, lasting throughout the project duration?

Quality involvement of the public in the decision making process is vital for the successful adoption of a project. For change to be delivered sustainably the interests of numerous stakeholders must be finely balanced and across an increasing range of voices – from the public and also private sectors.

4 Entrepreneurial Urbanism, conflict and multi-stakeholder decision-making

“Central to the achievement of sustainable development is the reconciliation of economic and environmental objectives [...] Although the early environmental movement saw business as the villain of the piece, there is now a generally acknowledged need to consider the 'competitive environment' alongside the biophysical.” (Selman 1996, p. 127)

Writing in the mid-1990s, Selman describes the emergence of sustainable development following the UN Conference on Environment and Development's 'Agenda 21'. Here it is suggested that sustainability will be largely dependent upon local action and especially the reconciliation of the physical environment with that of industry and commerce. Agenda 21 is described as having sought: 1) to encourage the concept of stewardship in the management and utilisation of natural resources by entrepreneurs; and 2) to increase the number of entrepreneurs engaged in enterprises that subscribe to implementing sustainable development policies (Selman 1996). However, practical barriers are identified in the sense that such intentions may be seen as ambitious and “*strongly constrained by the economic realities within which the business community acts*” (Selman 1996, p.127).

Entrepreneurialism in reference to urban governance tends to be captured by a policy shift toward decentralisation and an emphasis on ‘local governance’ rather than ‘local government’ (Andrew and Goldsmith 1998). Harvey (1989) describes this with the term ‘Entrepreneurial Urbanism’ as a means to envisage this shift (Ward 2003; Chapin 2002). As noted above, UK regeneration through the 1980s was characterised by what has been described as an economic entrepreneurialism (Tallon

2013; Grainger 2010; Jones and Evans 2008; Gilg 2005). This was driven by a property-led urban regeneration emphasis up until the early 1990s and was replaced by a competitive bidding process for regeneration funds by New Labour. The Localism Bill (2010) in the UK is currently driving a somewhat devolved and entrepreneurial economic responsibility for urban development, with two governance strands; 1) enterprise and economic development through the introduction of sub-regional Local Enterprise Partnerships (LEPs) and, 2) community-led 'bottom-up' regeneration. However, Adams (2001) warns that any return to the economic entrepreneurialism of the 1980s must avoid its pitfalls whereby the environment ended up a concern "*only in specified geographical areas*" (Ibid 2001, pp.7-8).

After the publication of the Brundtland Commission Report *Our Common Future* (WCED 1987) there is an increased international recognition that sustainability may only be achieved by reconciling multiple dimensions (pillars) across a wide range of city stakeholders. Today we might consider this also to involve much greater levels of cooperation across public, private and community partnerships. This provides an important but somewhat daunting framework for action when seeking integration across numerous drivers and perspectives. Gilg underlines that this will inevitably require the "*emergence of a new paradigm of a collaborative, multi-stakeholder place-making mode for the new century*" (Gilg 2005, p.171). Healey's (1997) influential 'Collaborative Planning' outline an important role for argumentative (or 'agonistic') approaches as a possible means for engagement that leaves dialogue open for constructive conflict, debate, and re-evaluation of the urban landscape as a common resource. Perhaps this may also act to maintain a negotiable space for creativity and innovation - characteristics considered above as valuable for achieving urban resilience against uncertain futures. Subsequently the role of Soft Systems Methodology (SSM) as a way of problem identification and structure in complex multi-stakeholder environments is explored.

5 Structuring complex decision problems

5.1 Soft Systems Methodology for urban energy planning

Sustainable planning of urban energy infrastructures has become one of the priority issues in the energy policy agenda, intensified by issues like natural growth rates, the flow of people from rural and less prosperous areas, environmental concerns and scarcity of resources. However, planning urban energy systems is a complex decision making process inherently involving multiple issues (changes in the organization of energy markets, several energy carriers and energy distribution networks and also consumers, builders, manufacturers and planners of the machines, vehicles, buildings and transportation networks that use energy), multiple and conflicting evaluation criteria (economic, technical, political, environmental and social), multiple stakeholders, multiple values and involving negotiations and trade-offs among key stakeholder groups with an interest in the planning process.

Being, by itself, a complex system, an urban energy system is only one of the several infrastructures of a larger and more complex system - the urban system. In addition to the infrastructures subsystem, the urban system encompasses other subsystems: Physical, Social, Economic, Ecological, Environmental and Institutional, which are interdependent and interlinked, and all these subsystems function together (Zia and Devadas, 2007) as presented in Figure 5.1. All these urban subsystems are directly or indirectly dependent on energy for their correct operation, being energy undoubtedly the precursor for the operation, growth and development of any urban system.

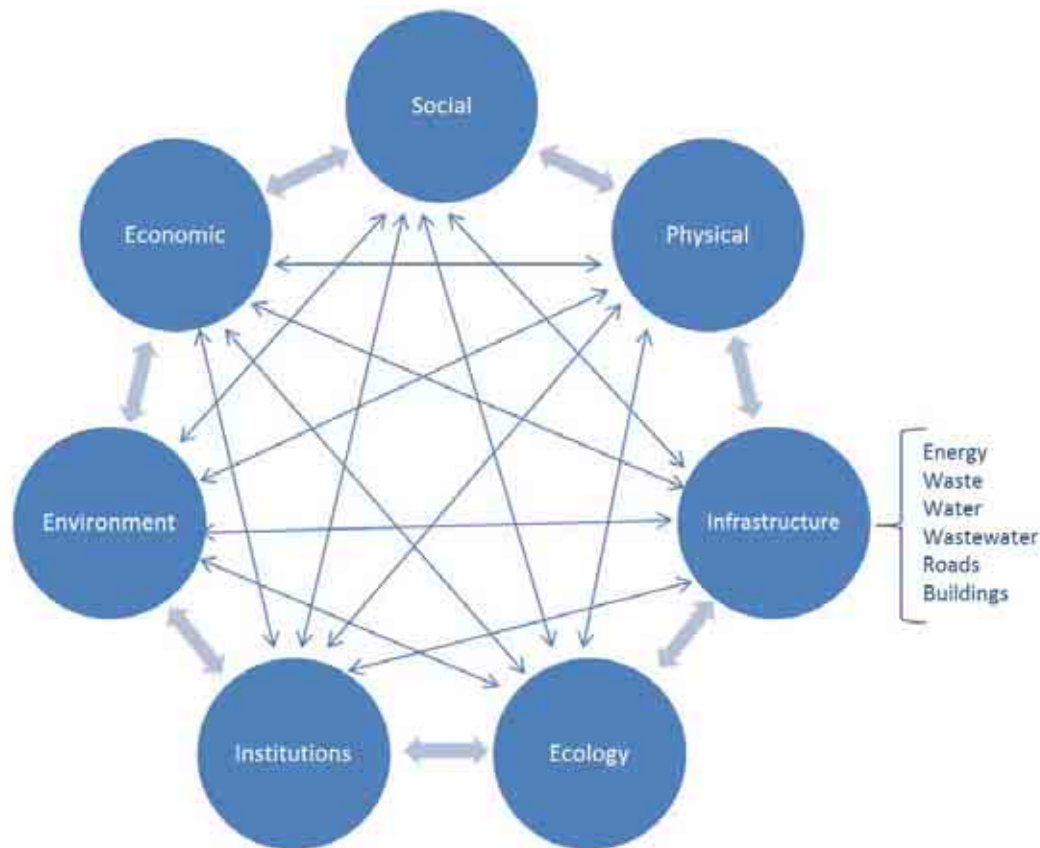


Figure 5.1 The urban system and energy interactions (after Zia and Devadas, 2007).

Several municipalities all over the world are addressing energy issues at the community level by pursuing initiatives to implement community energy plans, develop local renewable sources of energy, and encourage energy conservation and increased efficiency among residents, businesses, and municipal government entities. Municipalities have strong reasons to promote what can be considered as sustainable energy planning practices (CEC, 2005; European Commission, 2012). The municipality has several different roles in sustainable energy planning:

- Consumer and a service provider - the municipality is a major user of energy, being a large employer and property owner. Local governments are often big users of electricity in buildings and public facilities, in water systems and in other essential infrastructures such as streetlights.
- Organizer, promoter and regulator - the municipality is of decisive importance in town planning and urban construction, thanks to the municipal monopoly on town planning. The municipality is the public authority involved in licensing and inspection of various energy matters.
- Consultant, motivator and model - the municipality has the task of being a role model in energy matters. By training, education and sensitization, local governments can promote knowledge and have the task of being a role model in energy matters.
- Producer and supplier - some municipalities have municipal companies which incorporate function at the level of producing/distributing energy. The municipality can promote local energy production and use of renewable energy sources. Can also encourage citizens to implement projects related to renewable energy, giving financial support to local initiatives.

In order to allow municipalities and other local actors to be able to implement sustainable energy plans, effective decision support methods and tools for urban energy planning are required, taking

into account existing municipal, regional and national policies, plans, procedures and regulations that affect local energy and climate issues.

As discussed previously, any local policy decision making process should involve community members, as they are the ones who are affected by planning outcomes. Stakeholder's involvement in the urban energy planning process has multiple benefits. Stakeholders can contribute to ensure that public values are reflected in decisions to inform the public and to collect information on impacts that might otherwise be overlooked. The involvement of stakeholders also contributes to the legitimacy of the energy plan by building public support and brings confidence both for the decision process and to its outcome.

In a decision making process, decision makers have three main objectives: (1) to produce knowledge concerning the context of a problematic situation from whatever limited or limiting sources are available; (2) to apply it in the service of problem definition; and ultimately, (3) to plan systemically for action (Georgiou, 2008).

In this context, the following study presents the structure and formulation of problems, using an energy planning example, in an urban context through a problem structuring method, the Soft Systems Methodology (SSM). This structuring phase was the first step encompassed in the development of a methodological approach based on Multicriteria Analysis (Coelho, 2013) that can be used to facilitate decision making in sustainable urban energy planning problems.

5.2 Soft Systems Methodology: Concept and structure

Soft Systems Methodology (SSM) was developed by Peter Checkland (1981, 2000) as a process of inquiry and action for improving unstructured problem situations where the issues of concern are vaguely perceived but not clearly defined. SSM is suitable for ill-defined problem situations, where different interpretations can be considered and where there exist a high social, political and human component (Checkland, 1981; Checkland and Scholes, 1990; Checkland and Poulter, 2006).

SSM is described classically as a seven-stage process of analysis (Checkland, 1981), as summarized in Figure 5.2. In this model there are a sequence of activities, each one building on the constructs and insights derived from the preceding ones. Five stages are associated with the so called real-world thinking, two of them for understanding and finding out about a problem situation, and the other three for deriving change recommendations and taking actions to improve the problem situation. There are also two stages concerned with systems thinking, in which root definitions and conceptual models are developed. The sequence of activities does not need to be linear: it is possible to return to an earlier activity at any moment.

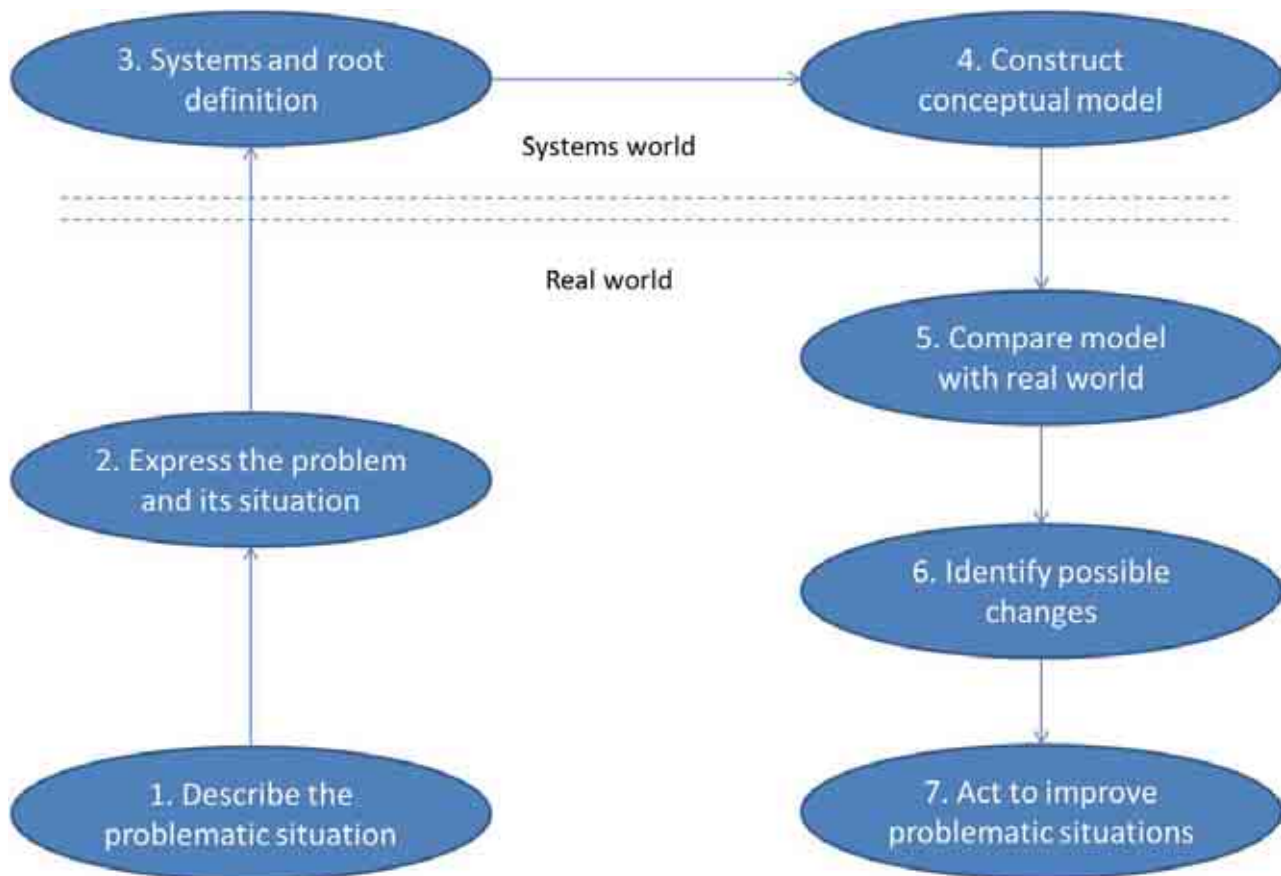


Figure 5.2 Seven-stage model of Soft System Methodology (after Checkland, 1981).

5.2.1 Finding out about a problem situation

SSM begins with the ‘finding out’ stage, conducted in the real world, and covers the first two activities: description of the problematic situation unstructured and structuring the problematic situation, where a description of the problem situation is made. There are different approaches to this first objective, a description of the social and political systems through the so-called Analysis I (to identify the client, the would-be problem solvers and the ‘problem owners’), Analysis II (to establish what social roles are significant, what norms of behaviour are expected from role holders, and by what values performance in role is deemed to be good or bad) and Analysis III (to find out through what ‘commodities’ is power manifested, and how these commodities are obtained, preserved and passed on), also referred as the stream of cultural analysis (Checkland and Scholes, 1990). In this step the main actors, their main roles and concerns are identified. The main results from the ‘Finding out’ stage are compiled into a rich-picture, a symbolic representation of the key actors and the relationships between them. The picture attempts to capture the attitudes, norms, values, and power relationships in the situation. Drawing a rich picture requires that the analyst works closely with the stakeholders so that the pictures capture the situation and related concerns from the stakeholders’ points of view.

5.2.2 Root definition and formulation of purposeful activity models

At this stage, the objective is the clear definition of a system’s model to use as a tool for learning. After selecting the most significant systems, SSM continues with the construction of the corresponding conceptual models, which comprises of steps 3 and 4, in the ‘systems thinking world’. However, before building the model, a clear and objective definition of the system to be modelled is required - the root definition. A root definition is essentially a sentence that describes,

in an abstract way, the fundamental nature of a system when viewed from a particular point of view. In order to be useful, a root definition should be constructed by consciously considering six components of the mnemonic, CATWOE (Checkland, 1981): the Customers (C), the Actors (A), the Transformation (T), Weltanschauung (or worldview) (W), the Owners (O) and the Environment (E).

Customers - are the victims or beneficiaries of the system who benefit or are affected by the output of the system.

Actors - those stakeholders who perform one or more activities within the system.

Transformation - is the core of the human activities system, where some defined inputs are converted at some output type and past back to the customers. The actors take part in this transformation process.

Weltanschauung/Worldview - assumptions made about the system or how the system is perceived from a specific perspective or viewpoint.

Owner - the individual or group that has the control over the proposed system. The owner has power to modify or even stop the system, overlapping with other actors in the system.

Environment - all systems human activities systems operate under certain restrictions imposed by the external environment, whether legal, ethical or physical. This is the environment within which the system operates and which influences the system, but the system has no control over it.

Table 5.2, based on Georgiou (2008), indicates these issues, along with some elements from the knowledge basis that enables supporting its information. Questions are asked for the identification of the various actors involved in the transformation process, according to their roles.

Table 5.2 The CATWOE elements and their basic sources of information.

Mnemonic	Terms	Questions	Informed by
C	Customer(s)	Who will benefit and who will lose from this T?	Analyses 1, 3
A	Actor(s)	Who will do this T, or make it happen physically?	Analyses 1, 3
T	Transformation	The T itself	Methodological rules
W	Weltanschauung	What reason or perspective justifies doing this T?	Analysis 2
O	Owner(s)	Who can stop or change this T?	Analyses 1, 3
E	Environmental	What restrictions are there in the immediate surroundings of this T?	Analysis 2

After subscribing root definitions, a conceptual model which is able to achieve the transformation described in step 3 is developed (Checkland, 1981). This model consists of a set of human activities thought of as a transformation process and connected by logical dependencies. Checkland (1981) points out that the definition of these human activities should be given by verbs that describe actions that players can directly perform (as gathering information, making plans, etc.) and not by verbs that characterize more consequences than actions (such as decreasing costs). While the root definition accounts for what the system is, a conceptual model is an account of what the system must do in order to be the system named in the definition. The model should include the monitoring and control activities to evaluate the quality of the transformation process based on the "criterion of 3 E's" (Checkland and Scholes, 1990):

Efficacy - (what is?) - The system works? The system allows the development of system objective?

Efficiency - (how?) - The system makes the best use of resources to achieve the desired result? The system works with minimum resources?

Effectiveness - (why?) - The transformation process has achieved long-term goals?

5.2.3 The system comparison stage

One of the most important stages of SSM is the comparison stage, the use of the built models for comparison and debate about the situation under study. During the comparison stage the conceptual model is compared with the real world system to highlight possible areas where changes are necessary. This conceptual model will identify where problems or deficiencies exist between what is happening (the rich picture) and what is desirable (the root definition) as defined by the models. To do this, it is extremely important the participation of those who are involved in the problem in order to generate debate about possible changes that may occur.

Checkland (1981) describes four ways of conducting this comparison: through an informal discussion; through a formal questionnaire; by describing scenarios based on the operation of the models, and by trying to model the real world in the same structure as the conceptual model. From the four ways indicated, the comparison using the formal questionnaire has emerged as by far as the most common, as described by Checkland and Scholes (1990). Using the formal questionnaire and looking for each activity and its connections established in the model, we try to evaluate whether such activity exists or not in the real situation, how it is performed and how it is evaluated.

5.2.4 Agree on changes and action

The discussion generated in the comparison stage should lead to decisions (by the clients and other relevant stakeholders) about changes which could be brought about to improve the problem situation.

Based on the comparisons made, it is possible to identify, in stage 6, proposed changes that will be necessary to include in the processes, in the structures and in the attitudes in the real system. At this stage we go back and draw on the knowledge gained during the problem expression stage, particularly in understanding how proposed changes might affect and be affected by stakeholders. Changes which are not agreed on will not happen.

The agreed changes will be implemented in step 7. The successful implementation requires that the proposed changes besides being desirable must be achievable. These adjustments may include changing the way certain activities are completed, or could result in the identification of activities not currently achieved in the real world. Checkland (1981) sees implementation as a new human activity, so we can start the whole SSM process over again. It is unlikely that the final outcome will match the agreed change exactly. During implementation new compromises will need to be crafted.

5.3 Application of SSM to urban energy planning

A medium sized Portuguese city has been used to test the application of SSM (Coelho et al., 2010). The city's urban area involves twelve civil parishes in a total of 107.11 square meters and 102,455 inhabitants; the number of existing buildings in the city urban area is 26,693; in 2010, the number of electricity consumers was 89,941, representing the domestic and non-domestic, respectively, 85.21% and 10.47% of consumers (Coelho, 2013).

For applying SSM to urban energy planning it was crucial all the information collected from the experts and representatives of a broad range of local stakeholders, obtained through various interviews. Public involvement in energy decisions serves several purposes. Some important ones are: to ensure that public values are reflected in decisions; to obtain information on impacts that might otherwise be overlooked; to inform the public; and to provide 'due process' in a way that the public perceives is fair. All of these purposes can help build public support for the decision process and outcome (Hobbs and Horn 1997).

The interviews have been conducted in several stages of the design process in the city which was chosen as a case study. In an initial phase, informal interviews were conducted with each selected actor separately. These actors were selected based on our knowledge about energy planning and on the information gathered from the literature review. These interviews included open questions and did not have a stringent structure. Questions were formulated with a view to identifying all the stakeholders that should be involved in the process.

During this first phase the interviews involved elements from different organizations: Regional Directorate of Energy and Geology, Regional Office of the Ministry of Economy, Energy Company, Local Authority (Alderman), Municipal Energy Agency, Energy Service Company; Universities and Research Institutes.

After identifying the stakeholders to be involved, several rounds of semi-structured interviews and some working sessions with a smaller group of actors were held. Those semi-structured interviews included specific questions for each stakeholder group and allowed, along with the working sessions, a better understanding of the role played by each actor, their degree of intervention and its power to influence decisions, the relationships between the various actors and identify their values, goals and concerns.

In the second round of interviews, the group of respondents were extended, including: municipal technicians, technicians from energy companies, local producers; bank technicians, lawyers, economists, architects, energy technicians responsible of large office buildings; residential and services consumers. The various working sessions that took place at this time involved municipal technicians and experts in various fields.

During the comparison stage, further interviews were conducted using a formal questioning.

5.3.1 Rich Picture

The information gathered through the interviews, allowed a complete rich picture (see Figure 5.3), with regard not only to stakeholders, but also to their role in the process and their relations of power. The following multilevel stakeholders, with different interests and preferences, appeared relevant, taking into consideration that a Portuguese city was chosen as decision scenario, as earlier mentioned:

International institutions – such as the European Union, can influence the directions to be followed in energy and environmental policies and set legislative rules for eligibility of financing through sources or programs. Require from the central government the compliance with international commitments (Kyoto Protocol, for example). Portugal, as a Member State of the European Union, has to comply with the EU Directives.

National government – is responsible by the transposition of EU legislation into national law.; demand for energy supply security, energy savings and rational use of energy, and conservation of the environment; analyse the international competitiveness of the energy sector National authorities provide regulatory and policy framework within which the other actors in local energy planning must operate and can influence the planning process by providing incentives for the energy companies to invest in new energy supply options. The central government encourages local government to adopt regulations that reflect good principles of energy planning and involve the public in the evaluation of a range of development options.

Local government - local authorities have the responsibility in urban infrastructures planning and can influence the economic and social situation at the local level and the development of local energy systems. Local authorities fulfil their functions in the energy sphere via a number of roles: as a consumer, producer, distributor and trader of energy; as a regulator, planner and policy maker regarding energy using activities and as a provider of incentives to improve energy performance. The local government is often powerful enough to influence the adoption of energy-saving technologies both by implementing tight norms and by creating the conditions in which adoption is encouraged.

Financial institutions – they finance local governments to support the planning and developing process of new plans. They also finance local producers to invest on renewable sources, consumers to invest in efficient technologies/appliances and the local government to support the planning process and develop new plans.

Energy agency – a municipal or a regional agency is essential in supporting the implementation of strategies and policies relating to energy efficiency, renewable energy, technology innovation, climate change and promoting sustainable development. Demands the involvement in the planning process; provides information; promotes initiatives and oversees the implementation of measures.

Environmental groups – interest groups, such as environmentalists analyse impacts from alternatives on environmental and social welfare; although they do not have a role in the legislation they exert an increasing pressure in this setting.

Manufacturers – provide technical assistance; usually support the implementation of some consumption reduction measures; aim to maximize sales. The end-use equipment manufacturers can be forced to bring efficiency to the market through standards or mandatory labelling. Manufacturers are faced by consumers demanding on energy efficiency at low prices.

Energy and local transport companies – they aim low costs and high revenues and a reliable supply compatible with the existing infrastructure. Establish a business relationship with consumers who request them quality of service at the lowest cost. Identify options for service to the community and try to incorporate them into strategic and operational internal plans. They are required, by law, to observe certain standards of environmental quality and efficiency. Have a great influence on the final decisions of urban energy system.

Technical officers – act as sources of information and consultants of decision makers; are forced to observe national and local rules and norms.

Universities - Many have research facilities that could be used for monitoring reductions in energy consumption and greenhouse gas emissions.

Local producers – demand an active role in the energy supply system; aim long life and an easy control of production systems. Its activity depends on national legislation on local production and also on the existing municipal rules and regulations. Local producers can benefit from the Energy Agency when implementing their projects.

Consumers – are concerned with energy costs, the protection of the environment and reliability of supply; react to new infrastructures and technologies; have enough power to influence the decisions of all the stakeholders.

Energy Service Companies (ESCOs) - allow obtaining energy efficiency improvements by accepting financial risks when they cover, or help finance the initial costs of investment. They can help public authorities to modernize buildings, grouping them into modular designs in the context of energy performance contracts.

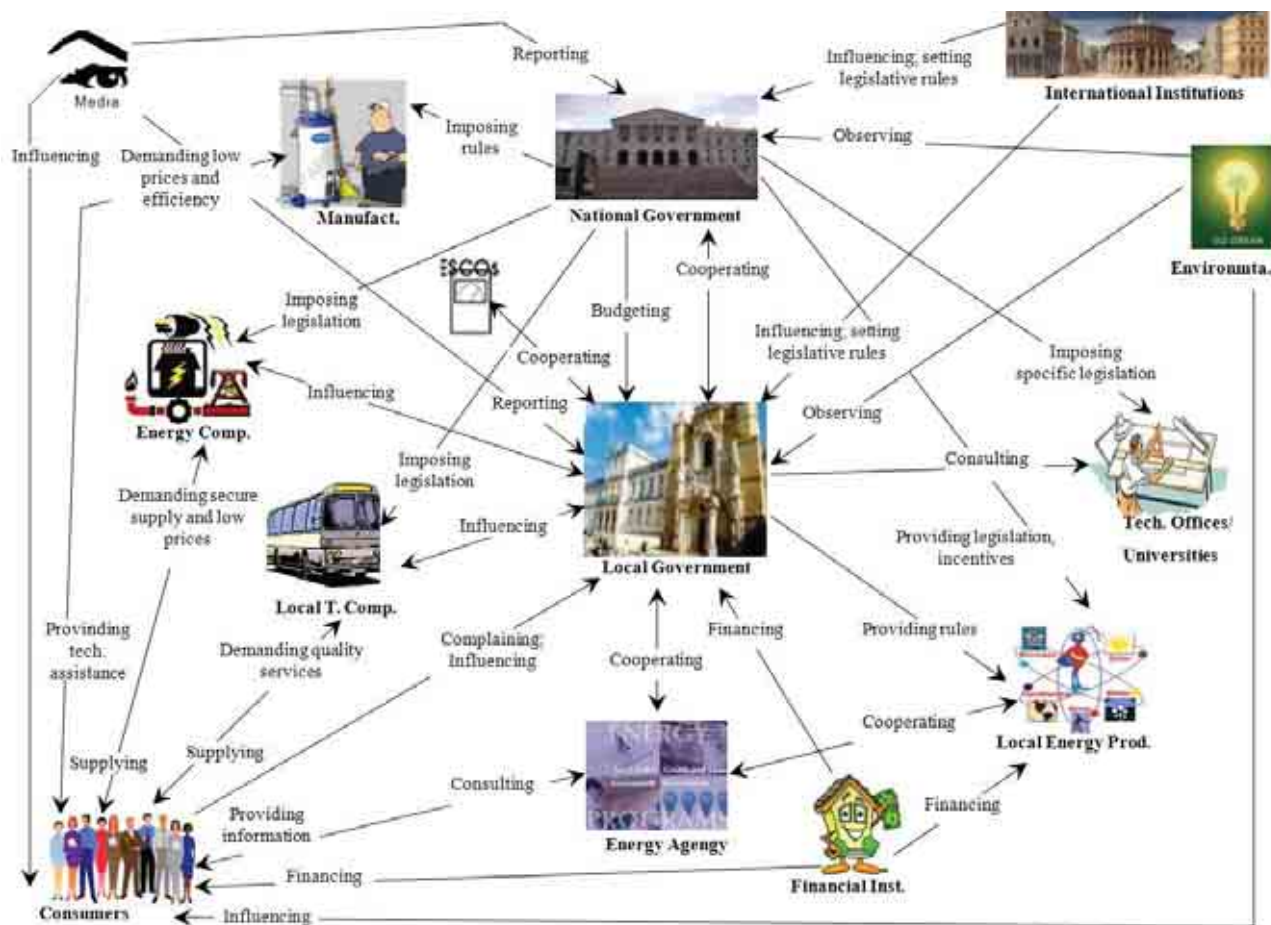


Figure 5.3 The rich picture of urban energy planning.

5.3.2 Root Definition

The construction of the root definition was guided by the CATWOE approach:

Customers – All the members from the city life/region: citizens, private and public companies, local authority, government bodies, manufacturers/traders who can benefit or be victims from the urban energy system. The beneficiaries will be consumers who, having freedom of choice, will benefit from a better and more secure energy system with lower economic and environmental costs; manufacturers that can benefit with the increase of sales of renewable energy technologies/equipment, citizens who benefit with job creation by implementing energy efficiency

measures and local production from renewable sources; the society in general, with regard to sustainable development and national energy dependence. Victims may be the energy companies that can reduce sales as well the manufactures of inefficient of technologies/equipment that will be replaced by more efficient technologies.

Actors – are the ones who know best the technical skills and requirements. A local planning committee composed by municipal planners, developers and consultants and energy companies' managers.

Transformation – changes that happen within or because of the system. Existing sectoral urban plans related with energy → an integrated urban energy planning that defines goals, policies and procedures in order to match future demand and supply in a sustainable way on the medium term.

Weltanschauung/Worldview – an integrated urban energy planning that aims to improve the decision making by supporting actors engaged in or affected by local energy planning in selecting an appropriate mix of energy technologies for the development of the infrastructures.

Owner – the Municipality, with a broader view on the problem, is the single decision maker considered. The Municipality is the authority of reference and has a prime concern for the system and the ultimate power to cause the system to cease to exist.

Environment – difficulty to access information and the ability to challenge existing planning; economic, environmental and technological constrains; international agreements and directives.

The following root definition lends to the CATWOE described above: “*A system to provide decision support to the Municipality, in the framework of sustainable development, to be operated by a local planning committee, which includes scenarios for energy demand and the identification of a portfolio of options impacting on the local energy systems (in the context of an overall vision of energy use) to be appraised according to multiple axes of evaluation*”.

5.3.3 Conceptual Model

While the root definition accounts of what the system is, a conceptual model is an account of what the system must do in order to be the system named in the definition (Checkland, 1981). The conceptual model is a model involving the minimum set of activities to conform the objectives identified in root definition. The conceptual model shown in Figure 5.4 was constructed from the root definition given previously. The diagram illustrating the modelling process consists of seven main activities, and also includes activities for monitoring and controlling the performance in the transformation process.

Activities 1 and 2 are related to the identification and collection of all data required for system development, namely: local availability of renewable energy sources (e.g. local data on monthly average solar irradiation and the monthly average speed wind); set of available energy carriers; set of energy conversion technologies; opportunities for improvements in energy efficiency; clean transport technologies; existing energy infrastructures; legislative rules. These activities may ask for energy demand models aimed at obtaining future amounts and forms of energy demanded, reflecting economic development and growth rates.

Activity 3 is needed to clearly define all the constraints related to the urban energy systems. These constraints can be legislative, environmental, economic and technical constraints as well as

constraints related with resources availability and capacity (constraints to the connection of microgeneration systems to the electric grid, for example). The constraints defined in activity 3 can make contingencies on the technology choice, whose impact on the energy supply and energy demand cannot be omitted.

Activity 4 is related with the evaluation of technology impacts, namely impacts related with investment and maintenance costs, with performance, reliability and safety, and also with the acceptability and applicability. The impacts on the urban energy systems and on the environment must also be evaluated.

Activity 5 needs the information obtained in activities 2, 3 and 4 for analysing supply options matching future energy demand in terms of amounts and forms of energy and map the energy infrastructure options. It requires the analysis of the existing energy infrastructure and the assessment of future energy supply options, using available resources and technologies.

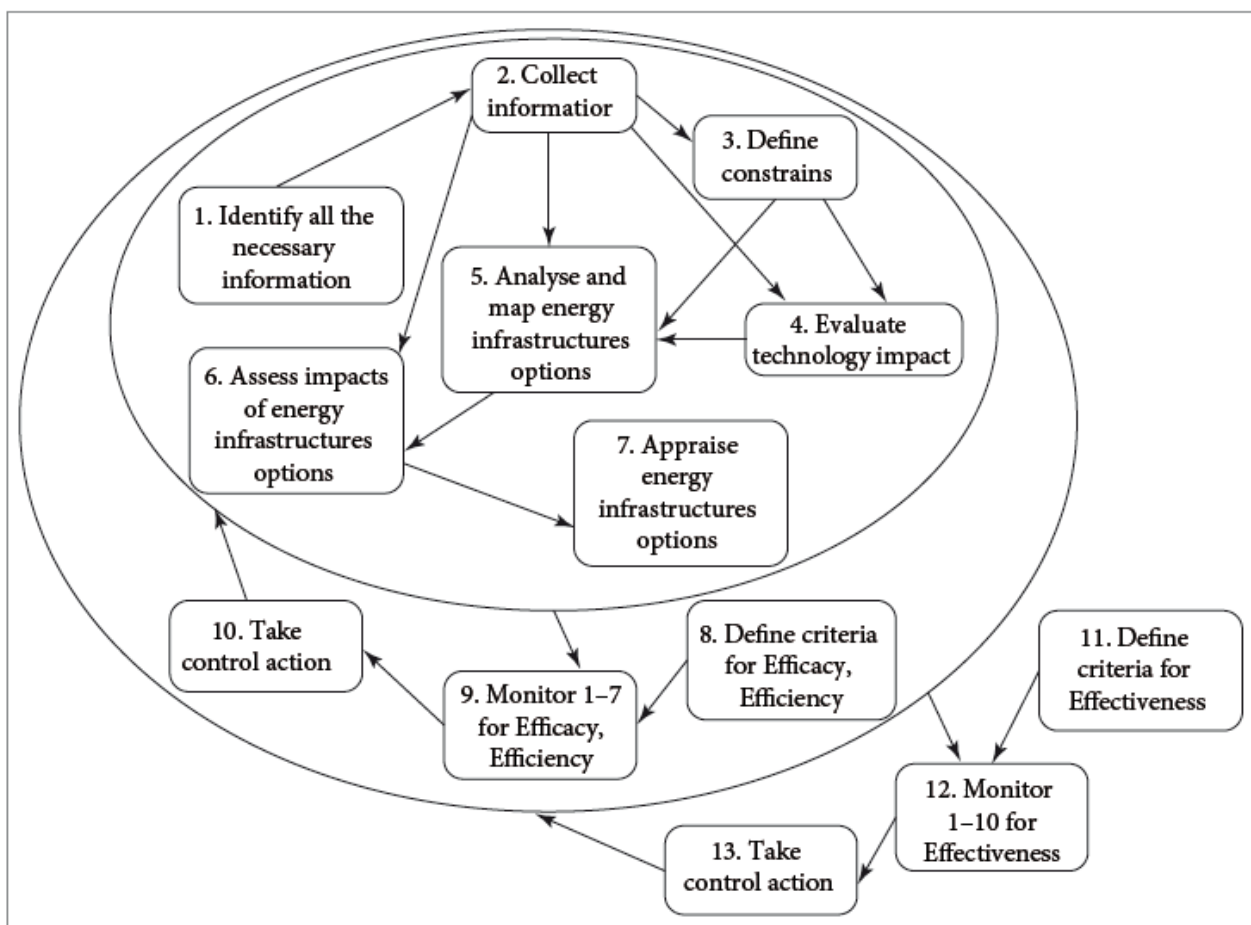


Figure 5.4 The conceptual model of the energy system.

In *Activity 6*, the assessment of the impacts of the energy infrastructures options is made. This assessment requires that the interests and preferences of the relevant stakeholders, extracted from the interviews and risen out from the structuring phase and root definitions are translated into criteria. The assessment must contain all relevant aspects, including aspects expressed in different units and even measured in qualitative terms.

In *Activity 7* the appraisal of options is made. This appraisal is the goal of this system and it emphasizes the need for a multi-criteria method that opens the possibility of incorporating the preferences of the Decision Maker (DM) into the decision support process.

Decision problems arising in the realm of urban energy planning are well suited to be tackled using Multi-Criteria Decision Analysis (MCDA) methodologies [Diakoulaki et al., 2005]. MCDA can assist local decision processes towards sustainable energy systems as it is able to deal with a complex process involving multiple issues, multiple and conflicting evaluation criteria, multiple stakeholders and multiple values on a local basis. MCDA offers opportunities to deal with mixed sets of data, quantitative and qualitative and to integrate knowledge from local stakeholders.

For monitoring and control activities in the urban context, the use of indicators makes it possible to monitor the return on investments:

Efficiency – expressible in money and time.

Efficacy – expressible in terms of options offered, purchased and provided at appropriate quality.

Effectiveness – can be guaranteed through the development of long-term sustainable strategies.

5.3.4 Comparison stage of urban energy SSM

The comparison was made in an informal way also supported with a formal questioning. Some issues raised from the comparison stage that should be taken into account are:

- Improve energy supply/demand analysis and forecasts;
- Perform and maintain municipal databases of information on local renewable sources and new technologies;
- Provide and maintain databases that hold statistical information of the energy sector as well as related to environmental impacts;
- Facilitate communication among participants and improve people's role component to identify opportunities to change;
- Perform a preliminary screening of the constraints in the main topics; maintain an observation process to evaluate constraints;
- Choose measures and units for all the indicators and determine scores on the indicators;
- Perform impact assessment through quantitative modelling or qualitative analysis; and,
- Use a decision support system based on a multi-criteria method devoted to classify alternatives in predefined ordered categories.

From the results obtained through the debate conducted in this stage, changes have been identified which could improve the problem situation. The assessment of changes is being carried out through discussion with the main stakeholders.

5.3.5 Concluding Notes on SSM application

Planning urban systems involve a complex decision making process inherently involving multiple issues, multiple and conflicting evaluation criteria, multiple values and involving negotiations and trade-offs among several stakeholders with conflicting views and interests in the planning process. Therefore, Multi-Criteria Analysis (MCA) approaches are essential to deal with these complex and challenging problems in the energy sector.

The need and advantages acknowledged by the explicit use of multiple criteria refer to the value-added of grasping a larger range of possible decisions embodying different trade-offs between competing axes of evaluation, also enabling a richer critical analysis of potential solutions. Furthermore, this methodological framework allows for the inclusion in the decision process of the preferences and interests of multiple stakeholders, in a coherent manner, in order to increase solution acceptance, incorporating the several sources of uncertainty at stake, enabling to obtain more robust recommendations.

For any MCDA application, the problem structuring phase is the starting point. The structuring and formulation phase of the decision problems is recognized as the first step - not the least - of a decision support process (Bana e Costa and Beinath, 2010; Diakoulaki et al., 2005; Franco and Montibeller, 2009) in opposition to the classic decision theory, where the decision problem is formulated in a unique way. Tsoukiàs (2007), referring to the unanimous opinion of several authors, based on several real world experiences, reinforces the idea that that structuring and formulating a problem remains one of the most critical parts within a decision aiding process. Although the decision maker possesses some of the information regarding the decision problem, most of the times it comes in a disorderly manner and needs to be structured.

Understanding a complex situation and usually poorly defined requires the identification of the main features of the decision context, the establishment of the scope and limits of the analysis, the identification of stakeholders and their main motivations and goals and also the classification of the potential actions that constitute the point of application of the analysis (Bana e Costa and Beinath, 2010). This will provide a well-defined operational base allowing the analyst to support the decision maker and other stakeholders in identifying the fundamental views and indicating the criteria for assessing the impacts of actions and consider their corresponding advantages and disadvantages.

While decision analysts have recognised for a long time the importance of problem structuring for successful MCDA interventions, most of them have relied on ad hoc practices for structuring the problem. Much of the MCDA literature neglects the role of problem structuring as a prelude to the structuring of an MCDA model (Franco and Montibeller, 2009).

The above example presents an SSM-based approach for structuring a framework for decision support in energy planning problems in an urban context as a first step for the development of MCDA tools to evaluate distinct courses of action. SSM concepts involve techniques that allow different interest groups to understand each other's points of view, express their own ideas and build consensus or compromise solutions. SSM helps decision-makers understand the 'real-world problem' by comparing people's perception with declared world-view models, and answering questions like: What is the problem? Why is the problem happening? How can the problem be solved? The SSM study has been used for characterizing as accurately as possible the decision problem context, identifying the main stakeholders and their relations, and discerning the relevant criteria at stake for each of them. The structuring phase rises out a set of interests, preferences and concerns of the relevant stakeholders and their relations of power.

The example provided here cannot introduce the whole issue in detail, its objective is only to draw attention to the fact that quality involvement of the public in the decision making process is vital for the successful adoption of a project. In our cultural environment, the perception of public involvement is still questionable and it is necessary to explain to the public the purpose of such a

measure and invite the affected citizens and interest groups to proposing the form of the future development.

Models for improved science-policy interface can help spread knowledge-based decision-making practices. Comparison of the four programmes shows the importance of being able to describe correct and measurable goals, as well as the lack of science-based planning-friendly decision-making tools for urban regeneration projects. In particular, a lack of design and assessment tools to examine synergies and conflicts between quality of life, of built surroundings and of environment seems prominent. The validity of implemented results can help generate financing mechanisms for exchange of successful concepts through policy or entrepreneurial activity, and can contribute to speeding up transition processes across the world.

6 Summary and conclusions

This section has traced the increase in complexity in the decision-making environment that necessitates integrated assessment for the sustainable development of cities. In many ways this sees a shift from urban interventions based on regeneration strategies and the uplift of urban fabric to much more holistic and multi-stakeholder approaches to the participatory planning of our cities. The Section charts a progression from a point where urban regeneration had predominantly focused on halting urban decline and encouraging investment in local economy as well as addressing social deprivation (quality of life having been high on the agenda). Across the European case cities a common theme of innovation and flexibility in planning systems are seen as a means of starting processes of capacity building in the cities. Some of the key political concerns were around strengthening the national urban systems, making cities more competitive and attractive to live and work in, avoiding urban sprawl, promoting urban regeneration, improving the quality of public space and built environment, functionality and energy efficiency, modernising infrastructure and service, ensuring social cohesion and employment. A new paradigm of public participation characterises these efforts and in the newly democratised Czech Republic for example, participation is viewed as key.

In any city, meaningful public participation requires a sensitive balance between the wishes of the public and specialist opinion and such stakeholder management and conflict resolution underpin the challenges associated with integrating sustainability measures. The key question posed here is how to reconcile public and technical opinion in increasingly complex city development - how to manage a successful multi-stakeholder participation process? Especially since involvement throughout all stages of the process is described as an important way of balancing stakeholder perspectives and maintaining positive and constructive dialogue. An increasing shift in emphasis from local government to local governance (entrepreneurial urbanism) is outlined as one of the significant new challenges to holistic and integrated city planning. The increasing factors affecting city development through devolved partnerships creates a challenging and complex decision-making environment and Soft Systems Methodology is presented as an important tool for managing the process of integrated understanding of cities and the necessary sustainability measures.

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Understanding cities: The way forward for integrated assessment

Section VI

Understanding Cities: The way forward for integrated assessment

Richard J. Dawson¹, Annemie Wyckmans², Efren Feliu³, Stephen Dobson⁴,
Jonathan Koehler⁵, Oliver Heidrich¹

School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne; NE1 7RU, U.K.;

richard.dawson@newcastle.ac.uk; oliver.heidrich@ncl.ac.uk

² *NTNU Norwegian University of Science and Technology, Faculty of Architecture and Fine Art, Norway;*

annemie.wyckmans@ntnu.no

³ *TecNALIA, Parque Tecnológico de Bizkaia, c/ Geldo, edificio 700, 48160 DerioBizkaia, Spain;*

efren.feliu@tecnaia.com

⁴ *Sheffield Business School, Sheffield Hallam University, Sheffield, S1 1WB, U.K.; s.dobson@shu.ac.uk*

⁵ *Fraunhofer-Institut für System- und Innovationsforschung ISI, Breslauer Strasse 48, 76139 Karlsruhe, Germany;*

j.koehler@isi.fraunhofer.de

Highlights

- Synthesis of key findings from this volume, that also draws out some cross-cutting lessons learned and advice for implementing an urban integrated assessment.
- Drawing on our experience from this COST Action and elsewhere we present a generic framework for urban integrated assessment to analyse the potential benefits and trade-offs of sustainability policies and interventions.
- An agenda for future research and application of integrated assessment is proposed, that considers challenges associated with improved understanding of urban processes, accelerating the uptake of integrated assessment and building capacity to implement and interpret integrated assessment.
- To deliver a transformative shift in our understanding of urban areas and provide the evidence basis for sustainable urban transitions we recommend establishing a network of systems-scale urban research and experimentation facilities.

1 Introduction

This concluding section first reviews the key findings from preceding sections of this volume, before reflecting more generally on some of the major lessons learned over the duration of this COST Action network. Drawing upon these lessons we present a general framework for urban integrated assessment that provides a starting point for any team seeking to develop such an assessment. Finally, we present an agenda for future research – with a focus on those topics most relevant to integration.

2 Synthesis of key findings

Section II provides a summary of case studies on integrated assessments from 11 European cities. A number of approaches to integrated assessment, from multi-criteria assessment through to advanced

model coupling, are reviewed. This showed that integrated sustainability assessment at the city/urban area level can be used to assess a wide range of sustainability issues. The main limitation of integrated assessment is that it is more complex than single disciplinary approaches: it might be more difficult to collect data, requires an extra theoretical basis for the links between different perspectives, and potential for more complicated modelling structures. However such assessments can then identify trade-offs, but also complementarities between the system components in the form of negative and positive feedbacks. Urban integrated assessments usually involve spatially explicit analysis and data. Our analysis shows that even in smaller European cities, detailed data is often available. Thus data availability was not a fundamental problem to delivering an assessment, although inevitably the quality of such assessments are inherently mediated by the quality of data. The biggest obstacle to unlocking the potential of modelling within the decision making process is that it takes time to perform and the results address many urban issues and therefore difficult to communicate. Crucial, as was shown in Trondheim and also recognised in the transition management literature, is the integration of integrated assessment methods into city level planning processes.

Section III highlights how addressing climate issues can stimulate integrated thinking. The section described the compilation and analysis of a database of published climate change mitigation and adaptation plans of 200 cities from 11 European countries. Although some two-third of cities had a mitigation plan, only about one third had an adaptation plan; and international climate networks e.g. Covenant of Mayors, seemed conducive to successful mitigation planning. Subsequently, urban planning and strategy policy documents related to climate change mitigation actions across 32 Italian cities were investigated. Different levels of ambition to reduce emissions (i.e. mitigation targets), reflect the different political commitment of the cities. Comparison between Italian and Spanish cities explored the influence of multi-level climate governance. This demonstrated the importance of constructing collaborative multi-level climate frameworks at the national scale that fully integrate with the local, city level, frameworks. Finally, an Urban Climate Change Preparedness Score for adaptation and mitigation climate change activities is proposed. The score provides a quantitative comparison of urban climate change action, based upon the content of mitigation and adaptation strategies, targets, timelines for action and progress of the implementation of these strategies across 30 UK cities. Section III also illustrated that climate change is an excellent stimulus for integrated thinking in cities. If assessed, planned and implemented together adaptation and mitigation efforts can provide opportunities and stimulate integrated thinking as they cross various sectors and administrative boundaries within and outside the jurisdictions and control of local authorities.

Section IV examines the role of green and blue infrastructures - with a particular emphasis on their contribution to resilience. Green and blue infrastructures are widely credited for providing an attractive visual environment and valuable ecological habitats. Well-adjusted to environmental and social conditions of a city, their social and environmental co-benefits are emphasized, and their presence lauded for improving citizens' quality of life. While the topic is gaining ground in policy and governance processes, the definition and implementation of green and blue infrastructures and assessment of their intended and unintended consequences are highly variable. The way the term and the idea is understood by urban planners, local authorities, local people and other stakeholders is still not clear and differs from country to country and from specialist to specialist. An examination of the strengths and weaknesses of green and blue infrastructures in policy and

governance, based on cases in Poland, United Kingdom, Czech Republic and Turkey shows wide variation in terms of quality, monitoring and documentation, and a large potential for improvement. These variations are partially due to differing climate drivers and responses, but also the varying degree to which the issues are acknowledged at the country, regional and local administrative scales. Tools for design and planning of green and blue infrastructures, such as eco-spatial indices, are available but not commonly used. It is important to understand and consider all the relationships between the components and agents of the urban metabolism, including the interaction between green, blue and grey infrastructures, and to develop indices and tools that can assess this systemic approach. Indicators and assessment tools are often linked to particular functions only, and do not assess the integrated nature of green and blue infrastructures in urban areas and therefore are not able to fully grasp their potential contribution to climate change adaptation and mitigation efforts in cities. As with climate change, green and blue infrastructures must be considered through an integrated lens to identify their full potential and how it might be embedded within the urban fabric.

Section V provides a policy and governance context, recognising the increase in complexity in the decision-making environment that necessitates integrated assessment for the sustainable development of cities. Urban regeneration policy from Norway, Portugal, Spain and the United Kingdom (UK) is reviewed and highlights that a coherent framework is still needed to test the impact of the instruments to transform local governance. Experiences from the Czech Republic demonstrate that the adoption of multidisciplinary approaches needs to embrace environmental psychology, urban sociology, municipal economy, statistics, architecture, urbanism, land use planning and legal studies. However, this requires a greater emphasis on multi-stakeholder decision-making, addressing potential conflict and alternative structures of governance and partnership for service delivery and development.

Planning of sustainable urban energy infrastructure has become a priority issue, intensified by issues such as population growth and demographic shifts, environmental concerns and scarcity of resources. An urban energy case study is used to explore how a soft systems approach to analysing and structuring complex decisions provides a useful mechanism for managing the process of integrated understanding of cities and implementation of sustainability measures. Across the European cases and theories discussed there is a common theme of innovation and flexibility in planning systems that should be seen as a means of starting processes of capacity building in cities.

3 Lessons for implementing an urban integrated assessment

The outcomes from the COST Action network described in the preceding pages of this volume have provided insights into many different aspects of the relationship between integrated assessment and sustainability in urban areas and cities. However, its main contribution has been to explore these issues from an integrated perspective. This enables consideration of some of the synergies and conflicts between different policies in order to develop portfolios of measures that together have a realistic prospect of achieving sustainable outcomes. Urban decision makers have always been conscious that urban and infrastructure development decisions can have a very long legacy, which may in practice be difficult to reverse. Urban sustainability is a remarkable stimulus to think on these extended timescales. Thus, development of integrated tools to understand the implications of urban planning, climate risks, as well as opportunities from green infrastructure – and the

governance structure to facilitate their implementation – are essential if decision-makers are to take more informed, evidence-based, decisions and long term planning choices.

Learning – from different countries, cities and different disciplinary perspectives - has been an on-going feature of this COST Action network. Based upon our experiences there are some key factors that we highlight as fundamental to the development of any urban integrated assessment:

- Identify the users and purpose of the assessment and adopt a participatory approach by engaging stakeholders throughout to ensure its policy relevance;
- Apply systems thinking to select appropriate scales and boundaries to address the phenomena and interventions of interest;
- Promote flexibility, learning and iteration within the assessment process to constantly improve the formulation of the assessment;
- Working within an appropriate uncertainty framework; and,
- Dedicate appropriate time and resources to the process of integration and its associated “overheads”.

These are now considered in greater detail in the following sections.

3.1 Engaging with stakeholders

Engaging stakeholders in a meaningful way is an important aspect of integrated assessment as the transition to sustainable cities necessitates interactions between citizens, governmental/non-governmental organisations, researchers, educators and businesses (Heidrich et al., 2009). By definition, integrated assessment is about conducting policy and issue-relevant research and analysis. However, the complexity of developing integrated strategies (which may involve demand management, land use planning and construction of new civil infrastructure) whose combined effect is more beneficial than the achievements of any single agency or organisation acting unilaterally, poses substantial challenges. This is greater still where there are limited institutional, human and financial resources and more immediate and urgent development needs (Bulkeley and Moser, 2007; Roberts, 2010). Whilst the technical aspects of an assessment are likely to be developed by experts, conceptual development and outputs can and must be shared with a wide group of stakeholders, to support the communication and debate around different interests and possible sustainability policies. Tools to provide such capacity are much needed, but they will be of limited value if not accepted by the potential user community (Walsh et al., 2013).

As considered in Section 5 of this volume, institutional arrangements and other soft systems are not always set up in ways that enable flexible and adaptive responses. This can be for a number of reasons including, a lack of review mechanisms, inappropriate processes and short term financial arrangements. Long-term, cross-sector, thinking is typically not mainstream, hence many interventions – even when well meant – incur unwanted consequences. Integrated planning across scales involves clearly defined national and regional visions for cities with broad and long-term perspectives, focussing planning and collaboration at local levels. This enables full use of the knowledge of local communities, taking into account their wishes and needs, whilst sharing responsibility between local should facilitate a sound social basis for management plans to be developed and implemented.

3.2 Systems view

The starting point of an integrated assessment process will be the policy-driven research question(s): this raises the issue of appropriate system scale and boundaries. Some of these boundaries may be at different scales – for example water resources in cities will be obtained from a larger catchment, commuters can travel substantial distances and electrical systems are typically national in coverage. The systems view of cities has been a longstanding theme in the academic literature (Berry, 1964; Forrester, 1969). The systems approach seeks to represent the interactions between different urban functions and objectives and therefore provides a coherent basis to analyse sustainability from an integrated perspective.

A crucial challenge is to identify the key processes, their interactions and the extent to which they can be represented appropriately in an integrated assessment. An element of pragmatism is necessary in constraining the scope of any study and may require a willingness to experiment with a range of conceptualisations. One aspect of systems approaches is the potential emergence of properties at the city-scale, which can be tested and explored, and can provide useful insights into the behaviour of coupled human-natural and engineered systems. Choosing the appropriate level of investigation influences the approach and the insights it can provide. There is a balance to be struck selecting appropriate resolutions (in time and space), the number of sectors modelled and the number of factors (variables) considered for an analysis *versus* being swamped by detail or being too complex to resolve computationally.

3.3 Flexibility and learning

Integrating across multiple issues, and working with an extensive group of stakeholders, requires flexibility. As modelling and analyses reveal new insights, interactions between those undertaking the integrated assessment and stakeholders lead to new understanding. Sufficient flexibility and adaptability is essential if these lessons are to be assimilated and acted upon whilst the assessment is underway. As understanding grows the integrated assessment is improved, refined and focussed.

An initial step is likely to involve conceptual development of the integrated assessment process which can be supported by both qualitative and quantitative investigation. The conceptual aspects identified must address key issues across the dimensions of interest, including the views of key stakeholders. An integrated assessment programme must therefore evolve as understanding of the specific research needs develops, data availability improves, and technical capacity increases. Over time, the research team and stakeholders are likely to change, presenting both challenges and opportunities, bringing additional and complimentary perspectives and skills, but also an overhead associated with bringing new members up to speed. Similarly, changes in regulation, institutional arrangements, data/information, stakeholder interest, priorities and awareness, technological advances will be inevitable, thus any long-term integrated assessment research process must be dynamic to remain relevant to decision-makers and state-of-the-art.

3.4 Handling uncertainties

Uncertainty is a fundamental challenge for long term urban planning. Improvements in technical capabilities and robust data can of course reduce uncertainty, yet it always remains an inescapable aspect of considering the future and appraising sustainability policies. Furthermore, coupling of analysis of different urban systems can introduce additional types of uncertainty. Hence, approaches which recognise and address uncertainty are critical to a successful integrated analysis.

Uncertainty analysis involves the identification of the sources of uncertainty in datasets, models and other components of the integrated assessment and the implications of this in terms of outputs of interest (e.g. future risks or greenhouse gas emissions). This is crucial to understand how predictions of interest to a decision-maker may differ under plausible variations in the assumptions in an assessment.

Many uncertainties, such as storm surge frequency, can be captured probabilistically. However, to suppose that many of the processes we are interested in could be forecast on a timescale of decades is quite unrealistic. Other uncertainties – where data is sparse or phenomena of interest that need to be considered are difficult to quantify, such as governance, social structures, and institutions – must be dealt with using alternative approaches. Methods such as fuzzy sets (Hîncu, 2011) and interval probability theory (Dawson et al., 2004) have been used to capture some such uncertainties, but many of the approaches explored in this use scenarios studies. These scenarios provide plausible and internally consistent projections – as opposed to forecasts – conditional upon a clearly specified set of assumptions. In many instances these enable generation of reasonably plausible bounds on quantities of interest within which to test the potential suitability of sustainability policies.

3.5 The “overhead” of integration

The integration of insights and information from a range of urban systems is a significant challenge. There are technical reasons for this as scales, models, systems, quantitative and qualitative information are not easily linked – their integration needs to be planned, designed and centrally co-ordinated. To achieve this requires a multi-disciplinary team and takes significant time to implement. Moreover, there are practical challenges of interpreting information from integrated assessments and assimilating their complex model-based evidence into decision making processes.

Inevitably this additional overhead of people and time has an associated cost. However, the benefits of an IA for long term urban management provide new insights and tools for policy analysis that were hitherto unavailable and provides a large potential for improving decision making in future. Given the complexity of interactions and the large range of possible futures and options available to decision-makers, it is hard to see how evidence-based policy analysis of sustainability in urban areas cannot be conducted and implemented without the support of systems-based integrated assessment. The overhead of integration, from the limited sample of case studies in this volume, is usually repaid several fold by the additional insights and opportunities that it reveals.

4 A general framework for urban integrated assessment for sustainability analysis

On the basis of our network findings, we recommend that those planning urban integrated assessment place interaction and engagement between researchers and stakeholders at the centre of the process (Figure 6.1), linking both hard and soft systems. It is now clear that an integrated approach must be much more than an exercise in modelling and data analysis. Reflection and learning are perhaps a natural human response as well as typical in management processes, but making them explicit and transparent, reinforces and emphasises these important processes which are key to successful urban integration.

From the outset, policy questions and drivers need to be defined by the end users in order to manage expectations and set a realistic scope for the assessment. Not only does this give the research

relevance in a policy context, it also gives the decision makers a sense of ownership and hence willingness to stay engaged in the process as it progresses, which is particularly important in an evolving policy landscape. Many of the long term changes that drive the analysis at a broader scale will be the same for most cities, i.e. climate change, population growth and economic change – although their relative magnitude and directionality can vary considerably. City-specific scenarios can then be developed; however, it is important to acknowledge that urban policy develops within a national and international context, not in isolation. Considering change over such a long timeframe is fraught with uncertainty, so it is essential that the assessment is set within an appropriate uncertainty framework.

Furthermore, the process of integrated assessment must form part of a wider ‘dialogue’ with the urban area – itself continually reviewed and updated as monitoring of the urban area reveals changes, as a result of deliberate design or via unexpected events.

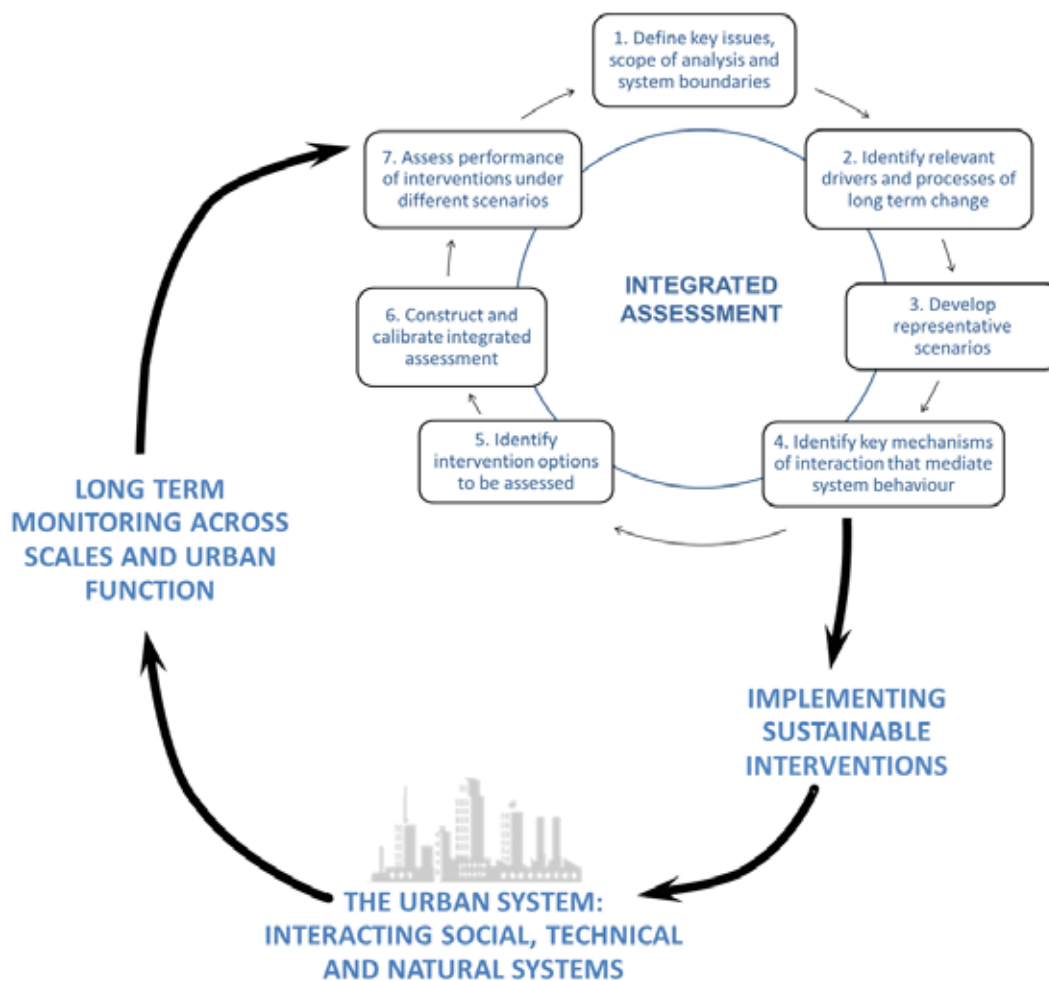


Figure 6.1 A generic seven-step approach to urban integrated assessment. The assessment is embedded within a cycle of continuous monitoring and intervention. (adapted from Walsh et al. 2013 and Nicholls et al., 2014).

5 An agenda for future research and application

This section so far has summarised many of the findings, and considered the lessons learnt, from this COST Action. Here, we distil the key research and development priorities associated with integrated assessment for urban sustainability. To avoid providing a list addressing every facet of

urban sustainability that deserves further attention, we focus on those issues that we believe are most pertinent to integration. Our recommendations address a range of issues, with particular emphasis on the need for systems scale understanding. Many of the technical issues might be considered incremental in nature, while the social and application issues raise more fundamental questions and challenges to the uptake of integrated assessment.

5.1 Improved understanding of urban function

It is clear that there are many urban processes relevant to sustainability that we do not yet fully understand. The complex topography and dynamics of the coupled human-natural-engineering systems in cities introduce substantial complexity, and evidently there are many instances where collection of more data and development of higher resolution, more sophisticated tools will help. Some other factors that we believe are priority areas to better understand the integrated nature of urban functions and processes are:

- *Exploitation of 'big data'*: Data availability is improving. Longitudinal surveys, often with qualitative data, are increasingly accessible online. Techniques such as remote sensing and intelligent sensors are becoming more accurate and densely deployed (e.g. Blythe et al., 2008; Tarek and Carsten, 2010). Even in areas of the world typically considered to be 'data poor' (Hagen, 2010; Map Kibera Trust, 2014) proliferation of mobile technologies has enabled data to be 'crowd-sourced' directly from members of the public to improve mapping, report faults and even help validate models used to analyse urban environments (e.g. photos to validate flood models (Newcastle University, 2014)). Linking formal and informal data could be a useful way to advance these methods and develop systems to assimilate and assess data as it is gathered. Present planning processes are rather poorly connected to these activities, making them a lost opportunity.
- *Focus on measuring and modelling interdependencies*: Urban areas comprise many interacting functions and sectors. Understanding these inter-relationships – amongst hard systems such as infrastructure and soft systems such as the economy – is essential to sustainable urban development. The majority of research is focused on individual sectors, often with the intent of joining uni-sectoral studies together in the assumption that this will enable understanding of the whole system. However, many interdependencies remain unnoticed without structured observation and study, or only emerge at wider spatial scales (e.g. Holderness et al. (2011) highlights this challenge in the context of measuring the urban heat island).
- *Integrating qualitative and quantitative issues*: Modelling studies in London, Paris and other cities reported within Section 2 (Koehler et al. this volume) highlight the potential of systems techniques to provide new tools to support the complex process of managing urban areas. Outside of Europe, other modelling initiatives are providing results in New York (City of New York, 2007), Durban (Golder Associates, 2010) and Hyderabad (Kit et al., 2012), whilst the World Bank is developing a generic tool to analyse institutional capacity and help prioritise adaptation options – including in slum areas. Despite these advances in integrated assessment modelling, integration of these quantitative assessments with qualitative issues, such as liveability and inequality, poses a more fundamental challenge.
- *Integration across scales*: We have already noted within this Section the importance of scale for integrated assessment modelling. A number of techniques are available for 'down-scaling' physical phenomena such as weather to urban scales, but techniques for downscaling other factors are much less well developed. Similarly, feedbacks from smaller to large scales are

often ignored as individual cities do often not register in regional or global contexts. As is shown the analysis of 200 urban climate change strategies in Section III it is crucial to understand ‘bottom up’ behaviour as the compounded action of large number of cities can have a notable global impact.

- *Models for coupled systems simulation:* Cities are examples *par excellence* of coupled human-natural-engineering systems. Urban modelling, indeed modelling of these coupled systems more generally, needs to make substantial advances in order to better model this complexity. These might include network theory to analyse socio-technical interactions, , agent-based (Parker et al., 2003; Dawson et al., 2011; O’Connell and O’Donnell, 2013) and other ‘bottom-up’ models, such as pattern-oriented models that use observed patterns to optimize model structure (Grimm et al., 2005), should be further developed to better understand changes in these systems across spatial, temporal and sectoral scales. Untangling these complexities can lead to new scientific study (Liu et al., 2007). New approaches should also consider qualitative systems modelling (e.g. Tur, 2002) to address some issues.

5.2 Accelerating the uptake of integrated assessment

It is clear that cities can most effectively meet their sustainability objectives, through integrated assessment of social, economic and environmental factors. Many cities have started in this direction but all too often these efforts are limited, set aside from the most important policies or confined to a handful of experts with the skills to develop and operate integrated assessments. Thus, there is an urgent need to facilitate the development of whole-system models through a range of advances:

- *Tools for integrating models and data:* As methods for integrated assessment improve, become better understood, and the number of case studies increases they should become easier and less costly to apply. However, a major barrier is that integrating data from different sources typically requires additional intermediary stages and significant expert input. Adoption of open standards in environmental modelling software, such as OpenMI (Gregersen et al. 2007) and development of frameworks (Harvey et al., 2012) that facilitate construction of complex model and data interactions could greatly facilitate the process of future integrated assessments. However, care must be taken not to construct valid software that ignores the relationship between the systems being modelled (Voinov and Shugart, 2013).
- *Open source models and protocols:* Standards, such as CityGML (<http://www.citygml.org/>), can assist the development and sharing of urban models. Similarly open source modelling codes have enabled wider application and analysis of certain phenomena. However, urban integrated assessments require a new generation of open source tools and data standards to reflect the much wider range of features that need to be considered and analysed – such as people, the economy and networks of infrastructure.
- *Generic and transferable tools:* Our review of integrated assessment modelling approaches in Section II revealed that data availability did not tend to be a barrier. Where less data was available alternative approaches, suited to that situation, could be devised. However, development of bespoke models is costly and so future research must focus on developing tools that are sufficiently flexible to be applied to a wide range of locations and data circumstances.
- *Dissemination mechanisms:* Informatics technologies are rapidly evolving and helping to change the way in which society (including policy makers) engages with urban information—advanced visualisation techniques and web-based delivery are examples of two mechanisms that

can help disseminate information more widely. As outlined in Section V further work is required to assist in the delivery and interpretation of the complex, multi-dimensional, sources of information from integrated assessments and the engagement of stakeholders.

5.3 Building capacity and improved decision-making

Understanding whole-system behaviour presents us with a set of challenges, and linking this understanding to urban management and policy, and stakeholders in general raises further challenges. Even if an integrated assessment is providing policy relevant results, policy processes are often not set up to ask these questions or adsorb and work with the results. It is clear from our experience that this understanding has to develop between researchers and stakeholders over time. Some developments that will improve the use and application of integrated assessments to inform decisions around urban sustainability include:

- *Capturing complex value and new 'business models' for delivering urban sustainability:* Direct economic costs and benefits are dominant factors in the process of appraising options. In the consideration of longer term sustainability interventions it is crucial to use a more sophisticated approach to assessing value. Assessment of more complex economic effects and the indirect impacts around issues of urban economic development – for example arising from major infrastructure investment must be captured. Many values are intangible and hard to measure, including issues such as amenity, social benefits, political costs etc. Hence, non-monetary approaches need to be further developed and brought into mainstream decision-making, possibly using methods such as multi-criteria analysis to help explore the ramifications of different choices. Typically a Return on Investment (ROI) approach has a tendency to focus on short term gains rather than longer term benefits.
- *Transition planning:* A sustainable urban transition is feasible in which, step by step, positive interactions between society, energy, transport, water, waste and other urban functions are exploited. This implies a clear need for methods and tools that can help to facilitate and inform decision making in cities through enabling the testing of alternative strategies and transition pathways within an integrated assessment framework (Koehler et al., 2009).
- *Socio-informatics:* Informatics designed for aiding human interaction has great potential in supporting long term urban planning. Action across so many urban functions necessarily involves a range of organisations that may have differing priorities and motivations. Spaces with multiple screens showing different perspectives on a problem, touch-screen devices, table-top computers and other emerging tools enable the creation of spaces to discuss complex problems interactively. Pilot studies have shown such collaborative environments can improve understanding the tensions between stakeholders (Walsh et al., 2013). If well designed, these socio-informatics tools can help tailor assessments and information to suit different stakeholders and governance contexts.
- *Training and education:* Building ongoing relationships with urban stakeholders is essential for the translation of integrated assessment results into policy. This requires that integrated assessment becomes routine and embedded within management systems. This includes training and education of both researchers and policymakers with the ultimate goal of moving these methods into practise. Supporting education programmes for early career researchers and practitioners would facilitate the acceleration of future development and the implementation of integrated assessment in practise. For example, during in February 2013 this COST Action

provided a training school for urban policy makers that focussed on integrated assessment and urban adaptation.

- *Cross-disciplinary research:* This COST Action has been a remarkable mechanism for consolidating knowledge around this topic. A number of examples of this are presented in this book. Having identified a number of priorities, a series of cross-disciplinary research programmes are now needed to develop innovative approaches to integrated assessment and advance ‘the science of integration’. Innovative mechanisms of research funding will be important to ensure collaboration between scientists and policy makers, and provide underpinning long term support to advance this important topic.

5.4 Understanding cities through systems scale experimentation

Even if the opportunities highlighted above are maximised, sustainable cities will remain an abstract concept unless we take a more systemic approach to understanding and engaging with our cities to build the evidence basis for sustainable decision-making.

Ecological research in the USA has benefited from structured, place-based research programmes. Twenty-six centres have, over 30 years, monitor a wide range of species, habitat types *etc.* to develop a richer understanding of the ecological system as a whole and consequently how it might respond to stresses such as climate change. A similar programme focusing on longer term change in the urban context could provide an unparalleled data repository and resource for urban research and provide important evidence and understanding of urban dynamics.

An integrated complex systems view of multiple urban functions, influences and feedbacks is crucial to understand urban infrastructure systems. Interventions, such as green spaces for flood management, are being made without monitoring to verify whether they are managing surface water flows as expected or considering the impact of greening (or other) long term changes in land use and infrastructure on phenomena like the urban heat island, quality of life and air quality.

To date, urban sensors have been used to develop stunning visualisations that show the movement of people and resources through the city (*e.g.* Phithakkitnukoon. and Ratti, 2011). Yet, a large disconnect remains between these visualisations of the ‘urban pulse’ and the social scientists and urban modelling communities who might exploit the richness of this data to better understand how cities work. A key aspect of this systems-scale experimentation would be to bridge this gap and fuse these multi-sector datasets to deliver a considerable advance in urban simulation modelling. Moreover, by monitoring across multiple urban functions and their interdependencies it will become possible to understand these interactions, and how they are disturbed by interventions.

Although there is overlap in the technologies that might be used, this is distinct in its purpose from ‘Smart City’ initiatives, which focus on short term efficiency and operations (European Parliament, 2014), as opposed to the systematic and structured approach to understanding urban systems we propose here. Inevitably, some findings will be specific to the case study city – although the experience from ecological research has shown lessons can be shared across typologically similar areas. To ensure sufficient coverage, we recommend systems-scale studies are established in a range of urban typologies.

6 Conclusions

The scale of the challenge facing the world’s cities through the 21st century is immense. Multiple drivers are placing a number of pressures on urban planners, politicians and engineers that require thinking over extended timescales, broad spatial scales – often beyond the boundary of the city

itself, and across multiple urban functions such as transport, water, energy etc. Given the multiplicity of factors and complexity of social, economic, environmental and engineering systems that interact in cities, traditional, linear analyses will not diagnose many of the problems or help identify appropriate interventions. As we have argued throughout this volume, there is a pressing need for advancing integrated assessment to support the delivery of urban sustainability.

Although significant progress has been made within this COST Action in terms of synthesising a wide range of existing activities from across Europe, a number of challenges remain. We believe that integrated assessment methods are fundamental to address this challenge from a management and policy-relevant perspective. The challenges span a diverse range of disciplines and include major gaps in our knowledge about the functioning and services provided by the natural environment, key governing physical process, and engineering and social sciences, including the link from science to management. However, despite these challenges there are a number of emerging success stories around Europe and further afield.

We have used our experiences to identify some generic lessons and principles to enable others to transfer our experience to other cities. However, cities all have unique social, cultural, economic and physical contexts – such that how a place may evolve and how change is managed will be distinct. The challenge of taking these ideas forward and further developing them should not be underestimated. At the same time the rewards and benefits are potentially enormous. In urban areas around the world, coalitions of policymakers and researchers across disciplines need to start engaging with each other and developing the capacity for integrated assessment. This will not be easy, the most significant benefits will not be instantaneous and there will inevitably be multiple routes to success. But these innovators will be laying the foundation for transitions towards sustainable urban areas across the world.

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Understanding Cities:

Advances in Integrated Assessment of Urban Sustainability

The urgent need to reconfigure urban areas to consume fewer resources, generate less pollution, be more resilient to the impacts of extreme events and become more sustainable in general, is widely recognised.

To address these issues, requires integrated thinking across a range of urban systems, topics, issues and perspectives that are traditionally considered separately.

This book introduces key results from the European Science Foundation funded COST Action TU0902 network that brought together researchers and practitioners involved in urban integrated assessment.

Using case studies, theoretical approaches and reporting experience from across Europe this book explores the challenges and opportunities of urban integrated assessment through four perspectives:

- (i) Quantified integrated assessment modelling;
- (ii) Climate change adaptation and mitigation;
- (iii) Green and blue infrastructure; and,
- (iv) Urban policy and governance.

The book closes by outlining priorities for future research and development and presents a generic framework for urban integrated assessment to analyse the potential benefits and trade-offs of sustainability policies and interventions.

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